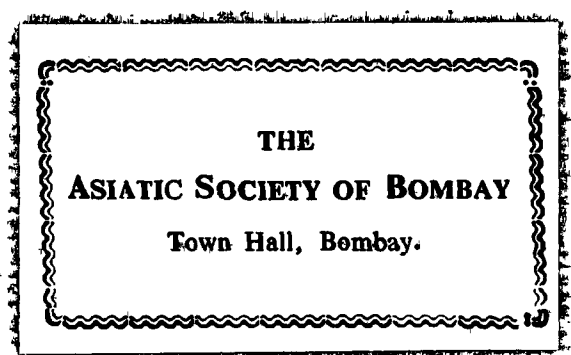


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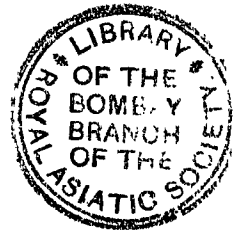
Government of Maharashtra

on 01 February, 2020

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PLATES.

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PREFACE.

My deputation to Italy to study the methods there employed for the utilization of silt for the mitigation of malaria and the fertilization of land was due to Sir Edward Buck, K.C.S.I., at one time Secretary to the Indian Government in the Agricultural Department. Since his retirement he has consistently maintained his interest in matters agricultural, and in the year 1905, when attending the Agricultural Conference at Rome, he seized the opportunity of learning and seeing what was being done in Italy in the way of the utilization of silt; and he was subsequently charged by the Indian Government to visit Italy and report on these methods.

The result of his visit has been a most interesting report entitled *The control and utilization of Rivers and Drainages for the fertilization of land and mitigation of malaria*, which gives an admirably clear and comprehensive survey of the history and objects of the works which are being carried out in that country at the present time. It also contains useful suggestions for the application of such methods in India, and it recommends, with that object in view, that one or more Irrigation Engineers should be deputed to Italy for the purpose of studying and reporting on the works which were there being carried out.

Sir Edward Buck accompanied me on my tour, which occupied the latter half of November and the first half of December of the past year, and my best thanks are due to him for his assistance with the arrangements for the tour and with the language, of which I have unfortunately only a slight knowledge.

I consider myself fortunate, too, in having visited these works with one who is well acquainted with the needs and conditions of India.

My best thanks are also due to the Italian Government for their kind permission to see the works, among the members of which I may mention Cav. Pasquale Acquaviva, Irrigation Secretary in the Public Works Department, who greatly assisted us and interested himself in our tour.

I should here also like to mention for their kind assistance and arrangement to see the works in their charge—

Signor	...	...	...	Ingenere	capo at Foggia.
Signor Ubaldo Lenzi	...	...	...	Do.	at Caserta.
Cav. Edvardo Ponti	...	...	...	Do.	at Grosseto.
Cav. Mederico Perilli	...	...	...	Do.	at Ravenna.

together with the Assistant Engineers who accompanied us on our tour of inspection.

I am indebted also to the Marquis Ridolfi for his kind permission and assistance in seeing the remarkable and interesting example of "Colmata di Monte," which has been carried out for the last eighty or ninety years on his estate at Mileto.

Lastly, I must not forget to mention Count Pasolino Passolini of Ravenna, who, himself keenly interested in agricultural improvements, accompanied us in our inspection of the works round Ravenna and gave us every possible assistance.

C. H. HUTTON.

REPORT ON THE UTILIZATION OF SILT IN ITALY.

SECTION I.

(1) In this report I do not propose to go over the ground already covered by Sir Edward Buck in his report—*On the control and utilization of rivers and drainages for the fertilization of land and the mitigation of malaria*—as this gives a very clear account of the past and present history of Bonificazione in a general way together with its object.

I propose, therefore, to deal in detail with the engineering side of the question by describing both the principles on which the works are carried out and the works themselves, as exemplified in those visited by us.

I must also, as the two are so intimately connected, at the same time, treat more fully of the agricultural side. Sir Edward Buck's report must therefore be read and studied as a preliminary to this one.

(2) By the term Bonificazione (the works of which are called bonifiche) is meant, in a general way, the improvement of the land, either from an agricultural or hygienic point of view, or from both together.

Definition of Bonificazione.

The works consist essentially in the hydraulic regulation or systematizing of the tract of country to be improved by regulating the courses of rivers and torrents, by systematizing their mouths, by erecting embankments to prevent inundation, by raising the level of low-lying lands or by filling up stagnant pools of water with silt derived from the turbid waters of rivers or torrents, by draining these same depressions either by means of cuts having a free outflow or by means of pumping, by filling up borrow pits along the line of roads, railways or canals with silt, wherever possible, or, if not possible, by providing proper facilities for their drainage.

(3) Omitting any mention of what has been done in Italy prior to the unification in 1862, already dealt with in the report mentioned, we may come to the period subsequent to 1862, since when a comprehensive scheme for the gradual Bonificazione of the whole of Italy has been evolved.

The Act of 1900 under which works of Bonificazione are now being carried out.

The Act of 1900, which is the legal basis of all the works now being undertaken, places upon the Government the onus of responsibility for undertaking the Bonificazione of all unhealthy lands, whether private or public; the exercise of the powers, conferred by the Act, being justified by the necessity.

(1) of lessening the difficulties of police supervision.

(2) of removing the causes of malaria.

The first object being explained by the fact that bandits and criminals have been in the habit of taking refuge in the malarial swamps, where the police are afraid to follow them. This is the case, too, in India in the malarious tract known as the Terai.

(4) By the Act of 1900 the works of Bonificazione are divided into two categories.

(1) In the first are included the more important works of drainage and colmata which have in view a great hygienic or a great agricultural amelioration of the condition of a tract of country, together with, in this latter case and as a result thereof, better hygienic conditions.

These works are carried out by State agency, or power to carry them out may be delegated by the state to the province or to the communes.

(2) In the second are included those works in which private interest is (a) dominant or (b) exclusive. These are carried out by private agency.

(5) Contributions to the expenditure on works of the first category are distributed thus—

The State pays $\frac{6}{10}$, the province and commune $\frac{1}{10}$ each; but this contribution of $\frac{2}{10}$ on the part of the province and communes interested is divided in the ratio of either the area or of the benefits derived, according to whether the area, which has derived advantage is or is not included within the limits of the work of bonificazione.

The proprietors also contribute $\frac{2}{10}$, to be divided among them in the ratio of the effective benefits derived.

(6) In the second category, where the interest is exclusive, the proprietors provide for execution of the works by forming themselves into voluntary associations.

If the interest is dominant the co-existence of a public hygienic or agricultural interest, although limited, imposes on the State or the provinces and communes interested to each provide, respectively, a grant-in-aid of $\frac{1}{10}$ of the cost, provided that the responsibility of the association may be declared on the initiative of the State or of some of the local authorities.

In other cases the possibility of subsidies from the provinces and communes is not excluded, but these same grants-in-aid are of the nature of advances rather than actual grants, and of the amounts thus granted reimbursement is in fact admitted after the work is completed, independently of the "plus valenza," (Enhanced value) which in every case remains to the advantage of the proprietors, whatever may be the category of the work.

(7) Easy terms of repayment are granted to the association whose quota of the above grant-in-aid may be recovered as an annual rate spread over from 5 to 30 years, according to the contributing powers of the authorities and proprietors interested.

The proportion contributed by the State nevertheless cannot be altered—*e. g.* in the case of concessions it cannot exceed $\frac{6}{10}$ of the amount of the projects carried out, with the addition of 12 per cent. for contingencies and unforeseen works.

(8) By whatever agency the work of Bonificazione may be carried out, it is obligatory on the part of the proprietors to maintain them at their own cost.

(9) Every care is taken to harmonize, in the best manner possible, the rights of private individuals with public requirements.

In case disputes arise over the question of expropriation or damage arbitration is provided for.

Not less care is taken to reconcile the common interests with the rights of individuals.

(10) In cases in which the majority of the common interests equally with the public interests predominates, an association must be formed to carry out works of the second category. The association must acquire the land from the dissentients and indemnify them for it by an annual rate spread over not more than 20 years.

(11) The proprietors are allowed to remain in enjoyment of their farms, with the exception of the buildings, during the execution of the works, and are allowed to remain in possession of their lands after the work has been finished provided they renounce the indemnity, which the association, under the law for the expropriation of land, must otherwise have paid.

(12) The public authorities and proprietors interested may form commissions of vigilance to insure that the work is properly carried out and in such a manner as to secure the object in view.

(13) The second report on Bonificazioni presented to the chamber of Deputies, contains some interesting statistics, from which I have taken the following figures.

In works coming under the first category—

	Acres.	Sq. Miles.
(a) Area liable to inundation ...	571,447	or 892
(b) Area always swampy, excluding above.	1,854,133	or 2,896
(c) Area under the torrents of Vesuvius neither liable to inundation nor swampy.	564,965	or 885
Total ...	<u>2,990,445</u>	<u>4,673</u>

Of this total have been—

	Acres.	Sq. Miles.
(d) already improved ...	1,255,085	or 1,961
(e) remaining to be improved ...	1,647,926	or 2,575
(f) Balance which comes under neither of the heads above.	87,535	or 137
Total ...	<u>2,990,545</u>	<u>4,673</u>

(14) The expenditure up to 30th June 1900 was Rs. 10,90,96,923 and up to 30th June 1906 was Rs. 13,53,29,235, or an expenditure of Rs. 2,62,32,312 during the 6 years that have elapsed since the Act of 1900 was passed. That is to say, the expenditure has been at the rate of Rs. 43,72,052 per annum.

In addition to this, in the same period 1900-01 to 1905-06, a sum of Rs. 13,93,818 represents the sum contributed by the State to works which came under the second category, and for a few works which are still being carried out under the law of 1882.

(15) There are no figures to show what proportion of the expenditure has been incurred on colmata, nor of the area in which colmata has been either finished or is still in progress, but there can be no doubt that works of drainage and protection from inundation have been and are much more extensive than the works of colmata: for example, at Capua the area under colmata is only 1/3 of the area under drainage.

I should say that of the total swampy area of 2,897 square miles certainly not more than about $\frac{1}{4}$, or say 700 square miles, or 458,000 acres, have been or are actually under colmata.

These figures include the work done before the unification, such as the Val di Chiana, but do not include the works being carried out under the second category, either by concessions or private individuals.

(16) Among the works mentioned in paragraph 2, as coming under the term "Bonificazioni," there are two methods by which a tract of land wholly, or partly marsh can be improved. One of these is drainage by free flow or pumping; the other is by raising the level of the land with silt (colmata).

It was for the purpose of studying this latter method in particular that my recent visit to Italy was undertaken.

Before, however, proceeding to describe the different works which were visited it will, perhaps, be better to set forth the general principles according to which these works are carried out.

(17) The term "colmata," which is derived from "colmare—" to heap up, means the process of depositing silt on low-lying lands for the purpose of raising them or for the purpose of fertilizing them. The

Definition of Colmata.

equivalent French word is "colmatage," which is derived from the Italian. For want of any English word which would convey the precise meaning I intend to use the Italian word "colmata" throughout this report.

(18) The art of colmata is undoubtedly Italian, and one of the first works of Bonificazioni undertaken in Italy was the improvement of the Val di Chiana in the province of Tuscany.

This work, which has consisted in the regulation of the torrents and drainages and also in the raising of the swampy and malarious low lands by means of silt (colmata), was commenced in the middle ages, and has been proceeded with up to the present time. The result has been that it is now one of the most fertile and healthy tracts in the whole of Italy.

(19) It may be stated here that the colmata of swampy lands with high spring levels, wherever possible, is generally considered preferable to drainage, as the results are more complete and satisfactory both from an agricultural and an hygienic point of view.

By agriculturalists especially it is considered "a grave error not to profit by fertile silt whenever it is available."

Preliminary investigation required prior to undertaking any project for Colmata.

(20) The preparation of any project for the application of silt to land must be preceded by a preliminary study of the quantity and nature of the silt at different seasons of the year in the waters of the rivers and torrents which it is proposed to utilize: also, of the mean volumes of silt which it is possible to obtain in a year or in certain seasons of the year. It must also be considered if the silt is suitable for the purpose in view, for silt may be applied to land either solely for the purpose of raising it, in which case as a rule the silt can be applied during any flood or at any stage of the flood, or for the purpose of rendering more fertile land which is already productive, and which does not perhaps suffer from defective drainage. In the former case the silt is applied once for all, but in the latter it may be applied from time to time.

(21) In the case of silt applied for the purpose of fertilization, it will generally have to be put on for shorter periods and at only predetermined states of the flood. Generally the lighter particles of silt in suspension, which predominate in the more superficial *strata* of the water, are those which it is desirable to apply to the land, and these are to be found more especially in a rising flood than in a flood at its full height or when falling.

(22) In the case where it is sought to improve the physical or chemical properties of the soil, silt of a clayey nature is required for the correction of specially light or porous lands; but, on the other hand, for lands which are heavy and of low permeability, silt with a large excess of sand is desirable.

(23) The volume and richness of the silt held in suspension naturally varies very much from one locality to another with the geological character of the soil, its cultivation, the velocity of the stream, etc.

(24) In general, the amount of silt is calculated at from 3 to 5 per cent. as a mean, and in the case of the Reno, in the province of Bologna, 7 per cent.

Methods of Colmata.

(25) According to Professor Nicoli, in his "Idraulica Rurale;" the raising of low lands with silt may be proceeded with in two ways:—

- (1) By diverting the whole volume of the river or torrent into the marsh, which when it is a shallow depression, only necessitates its being surrounded with an embankment to prevent the water spreading over the adjacent dry lands. In this case the basin so formed must be provided with escapes or overflow weirs of ample width to avoid an excessive raising of the water level, which would endanger the embankment.

The works at Manfredonia (Cervallo and Cancellaro torrent) at Piombino (Cornia torrent), at Ravenna (Lamone torrent), are examples of this system and will be described later.

- (2) By taking only such a proportion of the silt-laden waters of a river or of several streams, as will suffice for the purpose, by means of a diversion canal or canals, having either an open head or provided with a regulator fitted with gates.

The works at grosseto and Capua are examples of this system and will also be described later.

(26) The raising of low-lying lands with a deposit of silt have been classified by Professor Nicoli, as either "free" or "regulated."

Free and regulated systems of Colmata.

By the former is meant the partial or total diversion of the silt-laden waters of a river into a depression, the necessary works being limited to obtaining the supply of turbid water and at the most to directing and providing for the discharge of the water introduced into the depression. In such cases the stream takes the line of least resistance along the bottom of the valley and quickly begins to put itself into a state of equilibrium, by forming with its sediment both bed and banks, so that, in most cases this channel eventually divides the swamp into two parts which are most difficult and tedious to silt up. The constitution and the gradual successive raising of the channel carries with it a twofold result—

- (1) a large part of the silt is carried across the marsh in this new channel without being deposited ;
- (2) the bed of the river, up-stream of the swamp, begins to rise, often with the result that the hydraulic condition of the higher-lying lands deteriorates.

In conclusion, "free" as opposed to "regulated" colmata is irregular in its effect, is very slow in action and nearly always causes more or less damage to the conterminous lands, its only advantage being its low cost.

(27) Professor Nicoli in this same treatise lays down the following 4 laws with reference to the settlement of silt held in suspension :—

Laws of the settlement of silt held in suspension.

1. The precipitation of the heavy and coarse particles of silt (sandy) is far more rapid in each stratum than that of the light and fine (clayey) ; and probably the total depth of the turbid water has a somewhat less influence in the case of the former than in that of the latter on the duration of time necessary for complete precipitation.
2. By opportunely regulating the height of the stratum and the duration of the decantation, the sandy and argillaceous particles can be deposited in a determined proportion.
3. The clearing of the upper stratum is altogether more rapid than that of the lower stratum especially when the turbid waters are rich in fine and light particles.
4. It is convenient in order to shorten the time of precipitation, especially that of clayey particles, to limit the depth of turbid water in the basin and possibly to draw off the upper stratum (in which the precipitation is quicker) while still hardly clear, in order to be able to admit a fresh supply of turbid water.

(28) In treating of regulated colmata, by which is meant that the turbid waters admitted to the inside of the basin are diverted by means of secondary banks and channels and assisted by means of over-flow weirs in order to induce the deposition of silt in a more regular and

Regulated colmata.

more rapid manner, there are five methods which can be followed to secure the precipitation of the particles of silt in suspension, and the choice of one or the other has a very great influence on the duration of the operation. A layer of turbid water of height can be admitted into the basin, and then one can proceed with one or other of the following methods :—

- (1) By allowing the clear water after precipitation to be dissipated by evaporation or infiltration (if the bottom is not impermeable), after which a fresh supply of turbid water is introduced. This method is generally condemned, as it naturally takes a very long time. The action is intermittent but the sedimentation is complete.
- (2) By allowing the water to remain in the basin until it is completely cleared, whereupon it is escaped and a fresh supply of turbid water is admitted. A good deal of time is lost by this method, too, in emptying and filling the basins and, in the meantime, it is not possible to utilize the turbid water in the river. The action and the results are the same as in No. 1.
- (3) By discharging the water before it is completely clear. A greater quantity of the turbid water will thus be used, and the precipitation will be more rapid and the heavier particles will predominate over the lighter. The action is intermittent and the sedimentation partial or incomplete.
- (4) By decanting or running-off the upper stratum of water gradually and continuously, as it becomes completely clear, and at the same time admitting a fresh supply of turbid water. The action is continuous and the sedimentation is complete.
- (5) Under the same conditions as in the preceding case, the turbid waters are escaped before they are completely clear, and at the same time a fresh supply is admitted, the action being continuous and the sedimentation partial.
- (6) Methods 3 and 5 will result in a sedimentary deposit, in which the argillaceous particles are more or less absent.
- (7) Methods 4 and 5 will take the shortest time, because, in the first place, no time is lost in filling or emptying the basin; secondly because the precipitation in the upper stratum is, other conditions being equal, more rapid; and thirdly, because in this way the greatest volume of the turbid water of any flood can be made use of. Either the second or fourth methods must be followed where it is forbidden to discharge turbid water into the drains for fear of silting them up.

(29) Generally, when the amount of raising is considerable, a metre or more, it is desirable that the first deposit should constitute an open stratum, and, for this purposes, a deposit of the heavier sandy particles is required to secure which methods 3 and 5 should be followed. On the other hand, the upper stratum of 50 or 60 centimetres (1·5 to 2·0 feet), at least, should consist of a just proportion of clayey and sandy particles, rich in matter adapted to the nutrition of plants. As has already been mentioned these richer particles are, as a rule, the lighter and smaller, and are therefore the last to be deposited. To secure this either method 2 or 4 should be followed.

Other methods of regulated colmata.

(30) Colmata can also be carried out, in addition to the methods enumerated in para. 28, in either of the following ways :—

- (a) Turbid water may be admitted into a large number of little trenches, excavated in low-lying ground, when the silt, owing to the slackening of the velocity, will be deposited. This deposit of silt is then dug out and used to raise the

adjacent land, and the process is repeated until a sufficient height is obtained to render the land fit for cultivation.

- (b) The lands may lie along the course of an embanked river at a level but little above or below the ordinary water surface level. In such cases a supply of turbid water can easily be obtained for the purpose of either raising or fertilizing the land by constructing small outlets in its banks.

(31) Having fixed on the site of the basin (*baccino* or *cassa di colmata*) the area is surrounded with a strong bank to contain, if possible, the whole of the waters of a flood, or as much as the diversion canal is calculated to give during the occurrence of a flood. Arrangements must be made for the free drainage of the lands immediately outside the basin, and this can be done by means of percolation drains leading into a main drain, which it is generally found convenient to open along the outside of the marginal embankments.

Bo in of Colmata.

It is usually best to divide the basin into compartments by means of secondary embankments, which can be filled one after the other, according to the volume of flood water coming into the basin. By this plan the distribution of the turbid water can be regulated and the precipitation of the silt, the discharge of the clear water and the recharge with turbid water will be expedited.

(32) The internal network of drains which will be required when the work is completed must be foreseen, and the *colmata* must be so regulated as to give a suitable slope to the raised surface.

Drains.

(33) The following formula (variously applied in different places) gives the level *H* in metres to which the surface of the land must be raised above the mean level of the recipient of its drainage.

H in metres = $0.15 (d \pm 10 a) \times 2.0$, where (*d*) is the distance of the land expressed in kilometres and measured along the drain which leads to the recipient, and (*a*) is the height of the land in metres with reference to the surface of the water at the outfall of the drain, negative if above it and positive if below it.

(34) The frank of 2.0 metres (6.76 feet) in the above formula is the level the land at the outfall must have above the ordinary water level.

It is fixed on the consideration that it will be eventually reduced by settlement and consolidation by about one-third or to 1.34 metres (4.40 feet).

On the opening up of the percolation and agricultural drains it is considered desirable, for agricultural and hygienic reasons, that the sub-soil water should be not less than 0.80 to 1.0 metres (2.5—3.25 feet) below the surface of the ground.

(35) With the object of regulating the alluvial deposit various measures are adopted, such as extending the principal supply canal through the fan of silt deposit from time to time as required, opening up secondary channels to direct a concentrated volume of turbid water into the lowest places, or wherever there may be need of it, dividing off with banks from the main basin such areas as have been raised to the desired height.

Regulation of the Colmata.

The deposit of silt can be promoted by little cross banks, surrounding tracts nearly finished, and by opening up drains to provide earth for such banks. These drains should run in the direction of those which will be required when the work is finished.

(36) In order to be able to direct and regulate the operations intelligently a plan showing the actual and the required heights at intervals of 250 metres should be prepared, the actual heights being taken every summer when the basin is dry.

(37) As a rule it will be better to raise the higher land inside the basin first, in order that such lands may be quickly brought under cultivation.

When, however, there is but little slope in the diversion canal, colmata must be commenced in the more distant and depressed parts, otherwise the cone of silt, which is rapidly formed at the mouth of the canal, will cause the canal itself to silt up, with the result that the supply will be diminished. An excessive restriction of the basin may lead to the same bad results.

(38) Too large a basin on the other hand will render the regulation of the colmata more difficult, and, as already mentioned, it will be well to sub-divide it into compartments with banks somewhat lower than the marginal embankment.

It has been a common defect in the past to strive to inclose too much land.

The objections to this are :—

- (a) Greater capital expenditure in land, earthwork and masonry works, on account of the greater volume of water required.
- (b) Higher maintenance charges in consequence of the greater difficulty and expenses in guiding and regulating a larger volume of water.

Diversion Canal.

(39) The diversion canal should have its bed at its entrance into the basin but little below the level to which the ground at that point has to be raised.

Discharge sluices and weirs.

(40) The works for the discharge of the clear water from the basin are overflow weirs and discharge sluices in the marginal embankment, and are of a temporary or permanent nature according to the length of time the operations are likely to take.

Causes which have led to the falsification of forecasts.

(41) The following are the causes which have led to too favourable forecasts as to the time necessary for the complete colmata of a tract of land :—

- (a) Over-estimation of the amount of silt held in suspension.
- (b) Neglect to make any allowance for settlement not only of the new silt deposit, but also of the under-lying soil.
- (c) Neglect to make any allowance for silt carried away by the water discharged from the basin.
- (d) Neglect to make any allowance for lands raised accidentally higher than calculated for.

SECTION II.

DESCRIPTION OF BONIFICAZIONI WORKS VISITED.

Bonificazione at Ostia.

Drainage works at Ostia.

(1) The drainage works in the neighbourhood of Ostia, the ancient port of Rome, at the mouth of the Tiber, afford an interesting example of the improvement (*bonifica per prosciugamento meccanica*) of a low-lying and swampy tract of country by means of free-flow drainage and also by pumping.

(2) This tract is divided into three portions by the Tiber and the navigable canal from the sea to the Tiber: that to the south is called the "bonifica" of Ostia; that in the centre the "bonifica" of Isola Sacra; and that to the north the "bonifica" of Maccarese.

The area of each of these tracts is as follows :—

					Rs.
Ostia	...	...	...	...	4,693 acres.
Isola Sacra	...	...	...	...	2,346 „
Maccarese	...	...	...	...	10,621 „

(3) The works in connection with the former only were visited by us, but are typical of the others also.

The lowest lying land is 1.1 metres (3.6 ft.) below the sea level and the three depressions are separated from the sea by sand dunes. There are three series of drains which meet at the pumping-station.

One of the cardinal rules in connection with drainage works in Italy is that the high waters must be kept separate from the low and the turbid waters from the clear, more especially where pumping has to be resorted to.

These drains are known as the high, middle and low level : the first intercepts all the drainage from the up-lands and carries it into the basin below the pumping-station, where it flows freely away to the sea.

(4) As a general rule it is considered necessary that, during the rainy months, the level of the sub-soil water should be at least 0.60 metres (2.0 ft.) below the surface, in the case of pasturage lands or natural meadows ; and from 0.8 to 1.0 metres (2.6 to 3.3 ft.) if cultivated or planted out with trees. These rules apply to light soils only and, if they happen to be heavy and irrigated, the above amounts must be increased by 0.10 to 0.20 metres (0.3 to 0.6 ft.). This rule applies not only to the lands along the drain, but to the more distant tracts which must be put in the same condition by means of agricultural ditches (*fossi agricoli*).

(5) Plate No. 1 shows the system of drains in this case.

(6) Generally the percolation drains (*collettori*) are at 300, 500 or even 1,000 metres (984, 1640 or 3280 ft.) apart, while the agricultural ditches are opened at $\frac{1}{10}$ of these distances so as to divide the land into equal squares. It is found, however, that the land settles down and consolidates when it is dried by drainage and an allowance must be made for this in any drainage project to the extent 0.50 metres (1.6 ft.) or more in muddy bottoms; 0.30-0.20 metres (1.0 to 0.6 ft.) in moderately light soil and even less in clayey soils, while sandy soils settle hardly at all.

(7) As a general rule the slopes, of the intercepting drains should not be less than 1.0 to 0.50 per thousand according to whether the drainage waters intercepted are more or less turbid ; the main drains (*collettori*) can have a slope of 0.50 per thousand as a minimum and the percolation drains (primary) a minimum, of 0.10 per thousand and the secondary and tertiary a minimum of 0.15 to 0.20 per thousand. In the collecting drain the minimum slope should depend on the velocity of the water when in flood ; this should not be less than 0.30 metres (1 ft.) per second to prevent the excessive growth of weeds.

Minimum slopes for drains.

(8) The maximum limit of slopes in percolation drains is from 1.5 to 3.50 per thousand, and in collecting drains 0.5 to 2.00 per thousand with the reservation that light soils must not be subjected to a greater velocity than 1.0 metres (3.3 ft.) per second and strong soils to a velocity greater than 1.5 metres (5.0 ft.) per second. In the case, however, of drainage by pumping flatter slopes are given in order to carry off as much water as possible by free flow, and, although such slopes will necessitate the drain being cleared 3 or 4 times a year, the saving in the cost of the wear and tear of pumping will more than counterbalance the cost of clearing the drains.

Maximum slopes for drains.

(9) In cases where a considerable amount of silt is brought down into the contour intercepting drains it may be necessary to give a greater slope to prevent their becoming choked. In such cases two drains—a high and a middle level—may be substituted for the one at the high level.

(10) In this latter case, *viz.*, of pumping, the slopes of the collecting drain can be as low as 0.03 per thousand and of percolation drains 0.10 to 0.05 per thousand and of intercepting drains 0.10 or even less.

Slopes of drains when pumping is resorted to.

In both collecting and percolation drains the mean velocity in flood time, especially when pumping is resorted to, should be from 0.60 to 0.40 metres (2.0 to 1.3 ft.) or still better 0.70 to 0.60 metres (2.3 to 2.0 ft.) per second.

(11) Considering then a longitudinal section of the drain the flood level line should be at about ground level, and a line lower than this by 1.20 to 1.50 metres (3.9—4.9 ft.), with regard to what has been said previously as to the demands of agriculture, will represent the ordinary surface of the water in the rainy months and the bottom of the drain will be 0.20 to 0.40 metres (0.6 to 1.3 ft.) lower still.

(12) Situated above and below the pumping-station respectively, are the collecting basin (*vasca di arrivo*) and the discharge basin (*vasca di scarico*); generally rectangular in form and of a width and length double or treble that of the collecting or discharge canal in order that the effect of the draw in the first case or of the back-water in the second may be as small as possible. The bottom of the collecting basin is put 0.50 metres (1.6 feet) below the bed of the collecting drain and near the pumps it is 1.0 to 1.5 metres (3.3 to 4.9 feet) deep.

(13) It is considered sufficient, both in regard to agriculture and hygiene, if the pumps maintain the ordinary water during the rainy months at its normal height which means that the pumps must raise c. m. 0.06 per square kilometre (5.6 cft per square mile) and this is the factor adopted generally for the Agro Romano, i. e. the country round Rome.

Ostia pumping station.

(14) In the Ostia pumping station there are two turbine lifts one for the middle level and one for the low level. The following table gives particulars as to lift and discharge.

MIDDLE LEVEL TURBINE.

Maximum lift 1.7 metres (5.6 feet) discharge 4.500, c metres per hour (44.5 cusecs).

Average lift 1.0 metres (3.3 feet) discharge 7.500, c metres per hour (74.2 cusecs).

LOW LEVEL TURBINE.

Maximum lift 4.0 metres (13.1 feet).

Mean lift 1.8 metres (5.9 feet).

Low lift 1.3 metres (4.2 feet) discharge 3.600 c metres per hour (35.6 cusecs).

The discharge of the high level drain was based on a rainfall of 36 millimetres (1.44 inches) in 24 hours, and that of the middle and low level drains of 16 millimetres (.62 inches) in the same time.

It was calculated that the number of days for which the pumps would run continuously would be 43 to 46.

The Horse-power required in the case of Ostia tract is 1.64 per 100 hectares (0.66 H.-P. per 100 acres) per 1 metre (3.28 feet) lift, and, in the case of Isola Sacra and Maccasere 2.81 and 1.52 respectively (1.14 and 0.60 H.-P. per 100 acres).

(15) The statement No. 1 appended shows that the average amount of water annually pumped off this area of 4,693 acres varied from 77.2 per cent. of the rainfall, 1.03 metres or 40.55 inches, to 51.0 per cent. of the rainfall 0.787 metres or 30.98 inches, and was on the average for the 9 years 1897 to 1905, 62½ per cent; the average rainfall in that period being 0.886 metres (34.88 inches); the amount of water raised, therefore, varied from 0.23 to 0.62 litres per hectare (2.1 to 1.1 cubic feet per square mile) and was a mean of 0.67 litres per hectare (1.5 of cubic feet per square mile). These results, it must be noted, are spread over the whole year.

Drainage factor.

(16) As a general rule the amount to be pumped is based on an off-flow of 1.20 to 1.50 litre per hectare, 10.9—13.6 cubic feet per square mile, varying with the nature of the soil.

For natural drainage in the basin of the Po., from 0.8 to 1.00 litres per hectare (7.2 to 9.0 cubic feet per square mile) is allowed and in the

Maremma 1·20 litres per hectare (10·9 cubic feet per square mile). The sections of the collecting drain, to be on the safe side are, calculated to carry 1·5 to 1·20 litres per hectare (13·6 to 10·9 cubic feet per square mile) according to the nature of the soil.

The land in the low levels, although for the most part cultivated, looks poor and sodden in spite of the drainage, and it is not easy to understand why the waters of the Tiber, which have a very high degree of turbidity, have not been utilised to raise the land.

(17) The income, before the drainage works were carried out, was derived from the sale of the fishing rights and amounted to Rs. 3,600 per annum on an area of 400 to 500, hectares 988 to 1235 acres, or Rs. 25 per acre. It now amounts to Rs. 68 per acre, or more than double.

Value of the land before and after improvement.

The present selling value of the land was stated to be as follows:—

Land fit for wheat	...	...	360 rupees per acre.
Ditto pasturage	...	...	216 ditto.
Ditto woods and coppices	...	...	120 ditto.

(18) The appended statement, No. II, shows the cost of these drainage works per hectare,

Table I showing the total amount of water raised and water due to rainfall over the whole area of 1900 hectares.

Year.	Water raised c. metres.	Rainfall in millimetres.	Water due to rain fall in cubic metres.
1897 ...	9,596,400	859·7	16,315,300
1898 ...	8,764,800	768·9	14,590,100
1899 ...	14,057,275	1107·2	21,036,800
1900 ...	13,477,200	1102·5	20,947,500
1901 ...	11,276,925	804·3	15,281,700
1902 ...	7,629,600	787·3	14,958,700
1903 ...	11,267,025	1031·1	14,590,900
1904 ...	8,056,950	768·2	14,595,800
1905 ...	7,457,175	750·7	14,263,300
Total ...	91,573,350	7979·9	146,580,100
Mean ...	10,174,818	886·6	16,286,677

Table II showing the cost of the Ostia Drainage Works in Lira.

	Ostia per.		Isola sacra per.		Maccarese per.	
	² K. M. 19.	Hectare.	² K. M. 8·5.	Hectare.	² K. M. 43.	Hectare.
Cost of construction	1,270,000	663	267,000	281	1,845,000	429
Annual cost of working the pumps and sinking fund capitalized at 5 per cent.	640,000	337	165,976	175	1,169,600	272
Annual cost of maintenance of all the works, less the preceding, capitalized at 5 per cent.	19,930	11	280,000	295	408,000	95
Total ...	1,828,830	1016	712,976	751	3,423,600	78

The ultimate cost of drainage of the Ostia tract will be Lira 1868 and of the Maccarese tract Lira 1706 per hectare.

BONIFICAZIONI AT FOGGIA.

Description of the tract
of country.

(1) Between latitude $41^{\circ} 24'$ and $41^{\circ} 53'$ of latitude and $3^{\circ} 29'$ and $2^{\circ} 57'$ of longitude (with respect to Rome) there is tract of country on the shores of the Adriatic, whose limits are the mouths of the rivers Ofanto and Fortore, and in the middle of which rises the promontory of Gargano.

This promontory induces the littoral current to follow curved lines at some little distance from the two deep bays which exist on either side; and thus, little by little, the sand, which was deposited with the slackening of the force of the current, has formed dunes which, together with the extension of the deltas at the mouths of the Ofanto and Carafelle, have inclosed these bays. In this way, deep salt lakes were formed which in the course of centuries underwent great transformations. To the north of this promontory the river Fortore and to the south, the rivers Candelaro, Crevaro, Carafelle and the Ofanto slowly deposited their silt in these bays which had been shut off from the sea.

In ancient days, before the Roman epoch, and also for some years after, the country was both populous and healthy, but the horrors of the Punic War first, and then those of the fratricidal strife between Cæsar and Pompey brought desolation and destruction everywhere.

(2) In addition to the above, the salt lakes, with the increasing deposits of silt, became changed into marshes and the river beds rose, with the result that when in flood they spread all over the surrounding country, which in consequence gradually became more and more unhealthy and malarious.

(3) The rivers Cervaro and Candelaro are of a torrential character. Rising in the Appenines they unite in the lower part of their course, where they collect the drainage of the surrounding country and form a great swampy region 26,676 acres in extent. Within this area are the Contessa lake 7,889 acres, the Pantano Verzentino 1,383 acres, the Colentano, the Salso lake, 1,156 acres, and the Sipontine swamp, 889 acres; but the lands to be rendered healthy in the valleys of the Candelaro and Cervaro measure in all about 69,481 acres or 108.5 square miles.

(4) In these low-lying lands the water remains stagnant on account of the natural depression of the surface of the soil and the difficulty of the drainage, which the sea resists with the continuous formation of bars and dunes; and, besides withdrawing from agriculture and pasturage thousands of acres of land, generates an intense form of malaria the fatal effects of which cause the surrounding country to remain deserted by the inhabitants of Foggia, Manfredonia and other towns with a total population of 160,170.

(5) From 1807 onwards many attempts were made, both by the proprietors and also by the Government of the time, to better the agricultural and hygienic conditions of the country-side; but they were for the most part unsuccessful, either through being badly executed or badly maintained, and so this unhealthy region remained uncultivated and uninhabited.

It was not until the Act of 1900 was passed, however, that any comprehensive project for dealing with this tract of country was carried out.

Works of improvement.

(6) Among the various projects which have been carried out are:—*vide* Plate No. 2.

(a) The confining within its bed of the lower course of the Cervaro torrent for a length of 3 miles and the construction of the first silt basin, 1,205 acres in extent, at an estimated cost of Rs. 1,91,090, to be followed by the construction of a second basin of 1,119 acres at a cost of Rs. 63,600.

(b) The drainage of Lago Contessa and the embankment of the Fosso Farano at a cost of Rs. 4,72,374.

- (c) The confining within its bed of the lower course of the torrent Candelaro for a length of 4 miles from the Foggia Manfredonia road to the first silt basin of 1,161 acres at a cost of Rs. 2,29,800.

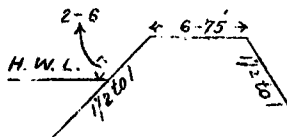
It is also proposed to embank the upper portion of the Candelaro and its affluents in order to prevent their flood waters spilling over the surrounding country.

(7) As soon as the first series of basins on these two rivers have been silted up, fresh basins will be constructed until the low-lying lands up to the sea have not only been sufficiently raised, but given a slope sufficient for the proper surface drainage of the land. The total estimated cost is Rs. 14,96,105 and it is expected the work will be finished in 25 years. This amount also includes the cost of the maintenance of the pumping-plant, &c., of the Sipontine marsh which began to work in 1899, the results of which have been not only most favourable to the health of the neighbouring city of Manfredonia, but have also made possible the cultivation of the land.

(8) The extent of land submerged in the valleys of the Cervaro and Candelaro is 26,676 acres. There are in addition 42,805 acres of swamps and marshes making a total of 69,481 acres or 108 square miles, of which 3,250 acres have already been improved, leaving 66,230 acres to be improved.

(9) The total cost up to the end of the year 1906 has been Rs. 12,16,698.

(10) The works visited in connection with this Bonifica were those of the Cervaro torrent which has a flood discharge of 7,000 cusecs. The whole volume of the torrent is diverted into the first basin, which is surrounded with a marginal bank of this section—



The banks are raised 0.8 metres (2.6 ft.) higher than the level fixed for raising the land with silt. This level is arrived at in this way: a height of 1 metre (3.3 feet) above sea level is allowed at the sea *plus* 0.25 per thousand for the drainage of the surface; thus a point 10 kilometres from the sea would be raised $1 + 10 \times 2.5 = 3.5$ metres (11.5 feet). The average amount of raising to be done in this case is about 4.5 feet. The average annual amount of deposit over the whole area of the basin is about 0.8 feet. The cost of making the bank is Rs. 20 per thousand c. ft. a labourer getting Re. 1-8 per day.

This basin has been in operation since 1900 and the silting is now practically completed and a second basin is under construction.

The unreclaimed land is very swampy. This is due not only to springs from the higher ground, but also to the fact that at high tide the sea floods the lowest levels.

Rupees 20 per acre is paid for this land when it is taken up for the purpose of these improvement works; it is poor land, only fit for grazing.

The silt deposited seemed to be particularly good, as also the strip of land along the course of an old river channel now completely silted up.

(11) The country from Foggia to the sea is singularly devoid of trees, but the soil appears to be very good and would, no doubt, be more productive if artificial means of irrigation were possible; but the summer months are very dry, and practically only one crop is grown, *viz.*, wheat sown in October. Large flocks of sheep come down in the winter to graze on the marshy lands and in the summer are driven up to pastures on the hills.

Method of working the silting basins.

(12) The methods of working the silt basins is simple. The inlet channel is continually being advanced as the silt is deposited, and subsidiary channels are also dug for the diversion of the turbid waters to the desired spots.

Escape.

(13) The escape is made at the lowest place. Plate No. 3 will show the kind of work.

The cill is at first 0·5 metres (1·6 feet) above the ground, and when the silt reaches this level it is raised with fascines another 0·5 metres : and so on until the required height of silting has been reached.

Overflow weir.

(14) In addition to the outlet weir an overflow weir is provided at the highest part, to prevent the banks being breached in the case of extraordinary floods.

Drainage by pumping.

(15) As has been already stated above, a small tract of low-lying land known as the Sipontine marsh, 889 acres, has been much improved by drainage. The water from higher grounds are intercepted by a high level drain along which the water flows away to the sea. The water from the lower levels has to be raised by means of a turbine pump. The lift is small above 0·25 metres (0·8 feet) on the average and 1·25 metres (4·1 feet) as a maximum.

Cost of pumping.

(16) The cost of pumping, clearing drains and general maintenance amounts to Rs. 10,800 per annum, or nearly Rs. 12 per acre.

The cost of the works, including drains, pumping house, machinery, &c., was Rs. 2,10,000. Briquette coal costs Rs. 24 per ton here.

BONIFICAZIONI AT CAPUA.

(1) The extensive alluvial plain which lies between the promontory of Miseno and Carinola constitutes the lower basin of the Volturno. *Vide* Plate No. 4.

The Volturno river has scoured a channel for itself through this plain in which, towards the sea, there are extensive marshes with dense vegetation.

(2) The backward state of cultivation in this tract before 1839 was due to several causes—first, to the formation of several lines of dunes which caused the waters between them to stagnate and also obstructed the drainage of the higher-lying land ; secondly, to the inundations of the Volturno. Both these causes gave rise to a severe form of malaria from the marshes which were formed. In consequence it was impossible for the cultivators to live on the land during the malarial season and cultivation was thereby greatly hindered. Thirdly to the difficulty of communication across a tract of clay soil owing to the absence of roads.

The works of improvement were commenced in 1839. An extensive network of drains, aggregating 227 miles in length, has been made to drain the higher lands and the turbid waters of the Volturno river and of the torrents Savone, Rivo Rota and Rivo S. Paola have been diverted to silt up the swamps and marshes ; a number of agricultural roads have been constructed also.

Great improvement in the condition of this tract has been the result of these works which are still in progress. Malaria has partly disappeared and inundations which were formerly so frequent have been prevented by embankments.

Volturno River.

(3) The maximum flood discharge of the Volturno is 71,000 cusecs, the mean annual rainfall at Caserta is 29·13 inches and the maximum 35·43 inches. The area of the drainage basin is 2,072 square miles of which 96 per cent. is hilly. Its bed slope in the plains portion is about 1·30 per thousand.

Amount of silt in the water of the Volturno.

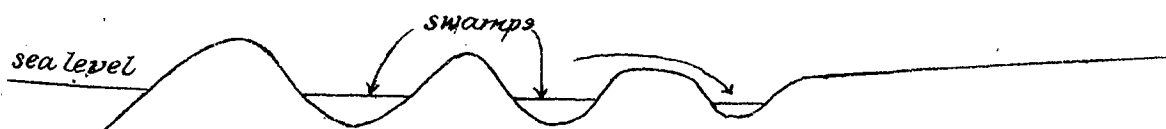
(4) The amount of silt carried in suspension by the waters of the Volturno is very great : it is about $\frac{1}{100}$ as a mean, or 1 per cent.

(5) The season of floods lasts from October to April, and it is only during this period that silting operations are carried on.

For the remainder of the year the canals are closed by earthen bunds thrown across their heads to stop all leakage, since some of the land under Clomata is then cultivated. For hygienic reasons, too, it is most essential that all the silting basins should be drained off as far as possible during the summer months, as it is in these months that the mosquitoes breed and that there is, in consequence, greater fear of malaria.

(6) The particular attention of the Engineers, here and elsewhere engaged in similar work, has been drawn by the Government to the necessity of draining off all water that would otherwise stagnate, and of clearing all jungle off the slopes of the canals to restrict, as far as possible, the breeding grounds of these mosquitoes.

(7) During the flood season there are about 27 floods lasting on the average about 3 days each.



(8) The sea has in the course of time thrown up a series of sand dunes along the coast, the section of the country being something like that represented in the marginal sketch. The hollows between the sand dunes are below sea level and are very swampy.

Reclamation of sand dunes.

This tract was under reclamation when we saw it. The tops of the sand dunes are first levelled off into the hollows; and then, as the dunes are composed almost entirely of light sand, the turbid waters of the Volturno are directed over the land for one season and allowed to deposit their silt: in this way a top stratum of good soil is formed which is sufficient to turn these dunes into good agricultural lands.

(9) The total area of the alluvial plain is 308,810 acres, or 474.7 square miles, of which 222,300 acres have been dried by means of drainage: 54,345 acres have been raised by means of silt from the waters of the river Volturno and the torrents Savone, Rivo di Lanzi, Rivo Rota, Fossoriccio and Rivo S Paola; and there are another 19,760 acres undergoing silting operations.

Silting operations (colmata) began in 1838. The expenditure up to the end of 1900 has been Rs. 1,38,00,000, of which 7.2 millions of rupees were provided by Government and 6.6 millions of rupees by the proprietors from a tax on the lands. Another six millions have been provided for the completion of the work, so that the total cost will be about 19.8 millions of rupees. The cost per acre will therefore be $\frac{198,00,000}{3,08,810} = 161$ Rs. The cost of the raising of the land by means of silt is no doubt very much greater, but separate figures for this are not available.

(10) The land which has already been raised by silt is very fertile and, it is said, will not require any manure for the next 10 years. The land after improvement is laid down as pasture for a year or two before being brought under cultivation. The principal crops are wheat and beans, sown in October and reaped in June and July, followed by maize sown either in June and reaped in September or sown in August and reaped in November.

(11) Silting operations are being carried on by means of three diversion canals *vide* Plate No. 5.

The first, however, on the left bank some kilometres above Canello, is still under construction. The canal bed at its head will be 0.5 metres (1.6 ft.) below low water in the river and will have a slope of 0.36 per thousand: 0.35 per thousand is considered to be the minimum slope to be given to such diversion canals to prevent the silting of their channels.

The maximum discharge of this canal will be 8,100 cusecs. Ordinary floods in the Volturno reach 15 feet above the low-water level and an extraordinary flood as much as 23 feet. The canal head or regulator, very similar to such works in India, consists of 7 spans of 4 metres (13·1 feet) each, with piers 1·5 metres (4·9 feet) thick, with a total width between the abutments of 37 metres (121·3 feet), although the bed width is only 12 metres (39·3 feet).

The down-stream slopes are protected for some 100 to 150 feet with masonry in lime, but no protection is considered necessary for the bed.

Besides this head there are several bridges for country roads, and two or three syphons for cross-drainage.

The head is set back from the river about 500 feet.

(12) The second canal on the right is below Cancellò. It has a bed width of 15 metres (49·2 feet), a maximum depth of 4·5 metres (14·7 feet) and a mean depth of 2·5 metres (8·2 feet). The maximum discharge is 5,000 cusecs; at a distance of about 2 miles below the head this canal bifurcates.

The head or regulator is of a very ordinary type, and the gates are raised by means of rack and pinion gearing.

Third diversion Canal.

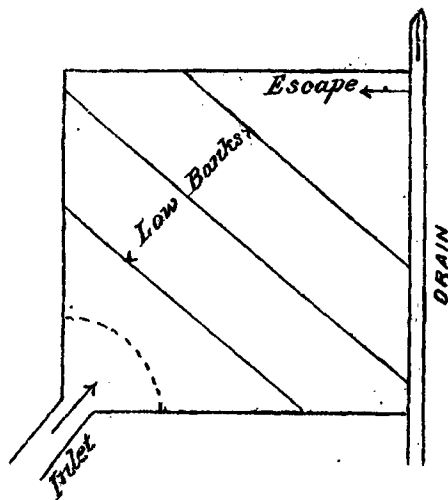
(13) The third canal is taken from the left bank of the Volturno. It has a skew head or regulator. The gates are here worked with screw gearing which, though slower in operation than the rack and pinion gearing, enables the gates to be got down more readily in the event of a high flood. These canals had no protection to the bed below the head, but showed no signs of scour. Neither of the two older canals showed any signs either of scour or of silt deposit, and were evidently well designed to carry forward the silt into the basins.

(14) The depth of silt deposit which was measured by me in two places averaged 4·2 feet per 3 years, or 1·4 feet per annum.

(15) The size of the basins in operation run up to 500 to 600 acres, but their limits are chiefly fixed by the boundaries of the different properties.

The marginal banks are kept 1 metre above water level.

The inlet channel is being continually advanced through the fan of silt deposit. Low banks are thrown up in succession about 1,600 ft. apart, and to the height to which it has been decided to ultimately raise the land. These are for the purpose of retarding the flow of water towards the escape opening, *vide* marginal sketch.



The level to which any point has to be raised is arrived at thus:—1·40 metres (4·6 ft.) at the sea above sea level, *plus* 0·1 per thousand according to its distance from the sea.

Escape.

(16) The escape for the clear water into the main drain is, as a rule, situated at the lowest place and is an open breach in the bank. If there is any danger of turbid water escaping into the drain it is bushed up with brushwood. It is considered very important not to allow such water to escape into the drains, as they might become silted up.

Drains.

(17) These drains are given a minimum slope of 0·20 per thousand which, with clear water running in them, is considered sufficient. As tracts of land are raised to the fixed height they are cut off from the

basin by means of banks and provided with drains. The silt deposit is wonderfully uniform, and no final levelling by hand ever seems to be required.

The cost of earthwork in canal embankment is Rs. 10·4 per thousand cubic feet, and of the excavation of the new diversion canal Rs. 11·7 per thousand c. ft.

BONIFICAZIONI AT GROSSETO.

(1) Before proceeding to describe the works of improvement at Grosseto and Piombini it will be both interesting and instructive to give a short description of the history and nature of the tract of country called the Maremma Toscana in order that the scope of the works there, as well as that of several other similar works in the locality (which however were not visited) may be the better understood.

The Maremma Toscana.

(2) The name Tuscan Maremma was applied at the beginning of the century to the littoral plain (the drainage of which is especially defective) between Livorno and the torrent Chiarone, forming the boundary between the provinces of Rome and Tuscany. As the country round Livorno became redeemed from malaria, so the northern limit of the Maremma came south to S. Vincenzo; from this latter place to the Chiarone torrent there is a littoral zone, 93 miles in length, which is separated from the sea by sand hills and dunes, and in which marshes, stagnant ponds and swamps succeeded each other in vast depressions. If one joins the two extremities with the Castel of Paganico in Grossetano on the right of the Ombrone, one has a triangular area of about 610,000 acres, and this includes that part of the country which, on account of its unhealthiness, is still called the Tuscan Maremma.

(3) The principal swamps in this tract are those of Piombini, Scarlino, Castiglione di Pescaia, Alberese, Talamone, Orbetello, Burano.

(4) In the time of the Etruscans the country appears to have been salubrious, and it is thought that it was after 300 A. D. that a littoral barrier commenced to form which, in the course of time, closed the Gulf of Castiglione and transformed it into a lake.

Past history of the Maremma.

The creation of these vast swamps and marshes has been due not only to the filling up of the bays of the sea with the silt brought down by the torrents, but also to slow undulating movements along the Tirrhenian coast which has raised some parts and depressed others. The swamp of Castiglione in the 14th century barely communicated with the sea, and at the end of the middle ages it had become pestilent and malarious. In the 16th and 17th centuries communication with the sea was completely cut off and the gulf became gradually transformed into a swamp.

(5) The gradually increasing unhealthiness of the country, due to the extensions of swampy lands, added to the invasions of the barbarians, the scourge of pirates and the fratricidal war between the Republic and the Signoria led to the desolation and abandonment of the Maremma; and it was only when the Medici rule was established that any attempt was made to remedy the deplorable state of affairs.

(6) It was not, however, until the house of Lorraine succeeded that of the Medici that a new era opened up, and henceforward the problem of improvement of this territory was kept in view. In 1765 the Grand Duke Leopold I called in the mathematician Ximenes to the direction of the hydraulic works, but little benefit was obtained from the works he carried out.

(7) In 1826 Leopold II, who had succeeded to the Grand Duchy of Tuscany, personally interested himself in the work of improvement and showed himself desirous of following in the footsteps of his grandfather. He first called in Professor Giorgini, who considered that the chief cause of malaria was the mixing of the salt water with the sweet and proposed works to prevent this.

(8) Fortunately, however, before, the works were much advanced Fossombroni, of Arezzo, who had become well known for his marvellous work in the improvement of Val di Chiana, appeared on the scene.

This latter, while showing his approval of the separation of the sweet water from the salt, counselled the adoption of the radical remedy of "Colmata," which had been resorted to in the case of the Val di Chiana. He proposed to utilize the silt in the waters of the Ombrone, the Bruna and the Sovata and he calculated that eight years would be sufficient to raise to the same level the whole of the Maremma of Grosseto, including the swamp of Castiglione.

Alessandro Manetti, however, who succeeded to the execution of the works, considered the period allowed too short and increased it to 22 years.

First diversion canal.

(9) In 1829 the first diversion canal was begun from the Ombrone at Buccace, with a bed width of 14 metres (46 feet) and discharge of 1,250 cusecs and a weir 3 metres (9·8 feet) high above the bed of the river was constructed below its off-take. The rivers Bruna and Sovata were also diverted into the swamp, but in 1854, as they had become harmful to the plains which had been raised, they were embanked and carried separately to the sea. The clear water from the basin was discharged through the outlet at Castiglione which was provided with the necessary works.

(10) In 1840 it became apparent that the roseate calculations of Fossombroni as to the time necessary for the completion of the work were not likely to be fulfilled, as it was found less easy than was supposed to conduct large volumes of water to silt up distant places, and moreover the water did not deposit the quantity of silt that had been calculated on.

First enlargement of the diversion canal.

(11) Fortified by this experience the enlargement of the diversion was carried out and its discharge increased from 1,250 cusecs to 16,700 cusecs.

The widening of the canal and other subsidiary works still did not produce the results hoped for, since there appeared defects in the weir and also in the regulator at the head, which passed heavy floods resulting in breaches of the banks and inundation of the country and much other damage. In addition to which, and for the same reasons, the canal ceased to function for no less than 18 years during the period 1830—72.

(12) In 1872 the Government of Italy appointed the Engineer Baccarini to make a full and comprehensive enquiry into the whole question of the improvement of the Maremma, and to suggest means adapted to push the necessary work on with more rapidity.

He found the diversion canal in such a condition that, instead of carrying the prescribed discharge of 16,700 cusecs as a maximum, it could hardly carry 3,800 cusecs in its lower portion, because the slope had decreased from 0·74 per thousand to 0·40 per thousand in consequence of the prolongation of the canal to 6·2 miles with the advance of the silting-up process. The silting-up of the bed resulted in frequent breaches and inundations of the surrounding country.

The system of drains, too, was found to be imperfect. They discharged their clear water into the marsh and hence reduced its capacity to receive the turbid water.

(13) His proposals were :—

- (1) To provide the regulator with gates to prevent the floods of the Ombrone having a free ingress.
- (2) To raise the banks somewhat and excavate the channel to allow of it carrying 10,700 cusecs as a maximum.
- (3) To take off from the diversion canal several branches for the purpose of silting up different portions of swamps.

- (4) To make further provision for the escape of the clear water and for the drainage of the country already redeemed.

(14) Although considerable improvements in the general conditions of the country were effected by the execution of the above works, still it very soon appeared that, in order to obtain more rapid results, it was absolutely necessary to utilize the largest volume possible of the flood water, so rich in silt, by sensibly increasing the section of the diversion canal; and in 1894 a fresh project, with this object in view, was prepared and put into execution in 1901.

Second enlargement of the diversion canal.

(15) The aim of the project is to utilise completely floods in the Ombrone up to 12,900 cusecs and proportionately those of higher floods up to a maximum of 21,000 cusecs, to remodel the regulator by giving it 6 bays of 4.66 metres (15.3 feet) span and to raise the weir by 1.10 metres (3.4 feet). Also the amount of super-elevation of the lands under colmata, and of those already raised was increased to allow for a settlement greater than was first anticipated.

It is now hoped that on the completion of these works, which are still under construction, that the colmata will be completed in 20 years.

(16) The reasons which led to the complete failure of the Engineers Fossombrone, Manetti and Baccarini in their predictions as to the time necessary to complete the work were as follows:—

Reasons of past failures.

- (1) The amount of silt, viz., 5 per cent. of the volume of the water as calculated, was not actually deposited.

- (2) The soil of the marsh was compressed by the silt deposited on it so that, as direct observations and calculations have already proved, two-thirds of the volume of silt deposited since the commencement of the works have, so to speak, disappeared.

(17) The tract under colmata has an area of 9,094 acres and is divided into two parts by the Canal di Molla and Collectore, *vide*, Plate No. 6.

Area under Colmata.

In addition to the 9,094 acres within the basin of Castiglione swamp there are 4,446 acres on the right and 5,253 acres on the left of the diversion canal which have already in part been raised and which will again have to be raised owing to the settlement that has taken place. The total area is therefore 18,793 acres, or 29.7 square miles. In the part to the left the more important are the three silt tanks called “della squadra alta del termine,” the open marsh, and the “della strillaie”; the Fossi dei Pescatori and the Emissario S. Leopoldi separate the first two. They receive the turbid water of the diversion canal which has its mouth in the open marsh, whilst the clear water is turned into the river of S. Leopoldi and Castiglione.

The part on the right constitutes the basins of Barbaruta and Raspollina between the Bruna, the Canal di Molli and the Collectore. The basins of Barbaruta and Raspollina and Castiglione delle Pescaie receive the silting water of the Ombrone from the regulator head, whilst the clear water is carried away into the plain of Castiglione.

(18) The enlarged canal has a slope of 0.415, so that the bottom, which is given a width varying from 23 to 48 metres (75 to 157 feet) in a length of 10 miles should not be below the plane to which the land is to be raised. The section of the diversion canal is designed to avoid or at least diminish silting up; and the object of the cunette is that silting-up should not take place as the water in the canal falls. Fig. 3, Plate 7, shows the cross section of the canal as now being enlarged. The maximum depth of water in the canal will be 6.8 metre (22.3 feet), the average depth of water 4.5 (14.7 ft.)—the minimum about 3.0 metres (9.8 feet). With the maximum depth running into the canal the mean velocity will be 2.2 metres (7.2 feet) per second, which seems very high for an earthen channel even when the bank's and bed are of fairly stiff clay.

Details of third enlargement.

It must, however, be remembered that the canal will run with full depth only occasionally and, moreover, the water contains such an enormous amount of silt that its power of scour is diminished. The canal will be worked between the 6 months November to April, these being the months when the greatest amount of rain falls. The average number of floods during these months is about 12, and their duration 4 to 5 days each.

(19) Fig. 2, Plate 7, is sketch-plan of the diversion canal at its off-take and Fig. 1, Plate 7, a sketch of the cross section of the weir.

Canal head.

(20) The canal head or regulator is built a little distance below the canal off-take, owing to the presence of a rocky barrier here which extends across the line of the canal.

The head is now being rebuilt to suit the present enlargement of the canal. It will have 7 spans, 4.5 metre (14.7 feet) wide by 6 metre (19.7 feet) high, which will be fitted with lift gates 4.6 metres (15.0 feet) wide by 7 metres (23 feet) high. The gates will be of iron plates with I beams at the back. The friction in the grooves will be diminished by a series of wheels in pairs continuously lubricated by means of a special system of pipes. They are made water-tight at the sides by means of a special arrangement faced with India-rubber. The raising will be effected through a chain actuated by an electric motor, and the power of the motor will be used also to assist the weight of the gate when lowering. It has been necessary to widen the existing road bridges, of which there are 5, and a new railway bridge at a higher level has been built.

(21) The total length of the canal from the off-take to its termination at the main basin, is 10 miles; at $5\frac{1}{4}$ miles from the head a branch canal takes off on the right with a discharge of 8,900 cusecs to silt up a depression there. When this has been completed this volume will be passed on to the main basin, the canal works and the section having been designed to admit of this being done. At $3\frac{3}{4}$ mile from the head the canal bed is about 1 metre below ground level and continues at about this level up to the main basin, so that the diversion canal is, for the great part, a huge embanked channel.

(22) With the full discharge of 21,000 cusecs, it is estimated that the silting basins will be filled in $1\frac{1}{2}$ days. The water will ordinarily be allowed to remain 10 days or so in the basin and will then be slowly drawn off from the top. It will take about 2 days to empty the basin.

(23) Up to the present time the clear water has been discharged into the sea by means of low weirs situated in the marginal embankment, and protected with fascines. It is, however, now intended to construct suitable masonry escapes for the discharge of the clear water.

(24) The depth of water in the basin when full will be from 2.5 to 3 metres (8 to 10 feet) as a maximum. The amount of silt still to be deposited within the area of the Castiglione swamp is estimated at 50,000,000,000 cubic feet, and 50 years is the period now estimated for the completion of the work and, if this is fulfilled, the total time from the initiation of the work in 1829 will have been no less than 170 years.

(25) The maximum flood discharge of the Ombrone is 85,000 cusecs. The amount of silt carried in suspension by the Ombrone is very great, as stated by the engineers it is $\frac{1}{10}$ by volume, i.e. 10 per cent. as maximum; but it must be remembered that it will be very much compressed when deposited and, as deposited, the proportion will probably be reduced to about 6 per cent.

Piombino swamp.

(26) The swamp of Piombino at the beginning of the XIX century was included between the sand dunes along the gulf of Piombino, the slopes of the hills of Populonia and the Via Aurelia.

Into this depression the Cornia river and the torrents from the hills empty themselves, *vide* Plate No. 6.

(27) But little was done prior to 1827, when the Engineer Giorgini proposed to prevent the salt and sweet water mixing, the improvement of the drains and the utilization of the rich silt in the Cornia for the purpose of colmata of the low lands, and the embanking of the upper course of the Cornia.

First proposal for improvement.

His proposals were completed by Manetti, and an outlet known as the "Penti di Capezzuolô for the clear water of the Cornia and for the drainage water was constructed. This bridge was furnished with moveable gates to prevent the ingress of the salt water.

(28) In 1872 the Engineer Baccarini made further proposals, which were also carried out.

However, as both diversion canals from the Cornia up to then had worked very inefficiently, provision was made in 1899 for a new rearrangement of the basin by extending it to 2,156 acres and for a diversion of the whole volume of the Cornia into it.

(29) This river has a maximum discharge of 31,400 cusecs, and its mean turbidity is 1.5 per cent. by volume.

Discharge of the Cornia.

(30) Silt tests are made by taking samples of the water at the height of about 1 metre above the bed in a receptacle holding 1 litre. Beakers holding half a litre are filled with the turbid water and the silt is allowed to settle and is then dried and weighed.

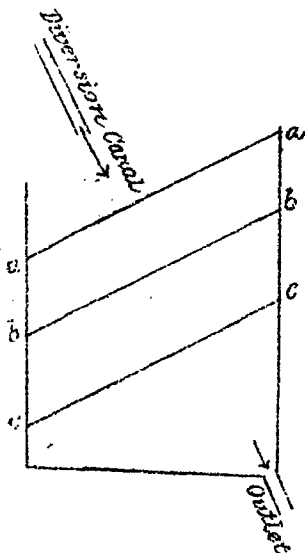
Silt tests.

A sample of silt was weighed before me and was found to be 74.6 grammes per litre. This works out in the proportion of 1 to 13.4, or 7.46, per cent. by weight. By volume this would be, taking a cubic foot of silt at 85 lbs. and a cubic foot of water at 62.4 lbs., 1 to 18.2 by volume or 5.5 per cent.

The maximum amount of silt as stated by the Engineer is 1 to 15 by volume, or 6.66 per cent.

Silting process.

(31) As has already been stated the whole volume of the Cornia now flows into the Piombino basin through the two diversions which are shown on the plan. These are gradually advanced as the silting up process takes place. The two diversions are divided by a bank in order to silt up more quickly the portion marked A on plate No. 8, and to give the water issuing from the second diversion a longer course before it reaches the escape at Torre del Salle. The colmata is frequently helped by subsidiary bunds a, b and c, as per marginal sketch, in which weirs are formed protected with fascines to allow of the passage of the water from one compartment to another.



(32) There are on the average about 12 floods between the months of November and June, lasting about 12 hrs. each. The earlier floods are those which, as a rule, bring down the greatest quantity of silt, as at that period of the year the agricultural land in the hills has all been ploughed up, and the surface soil thus loosened is easily washed down by the rainfall.

Floods in the Cornia.

Mean floods run about 5.0 ft. and maximum floods about 13 ft. above the low water stage.

The Cornia is embanked on both sides and when in full flood, the water level is 8 to 10 ft. above the level of the country.

Depth and volume of silt deposit.

(33) Levels are taken every year during the summer season to show that the colmata is progressing.

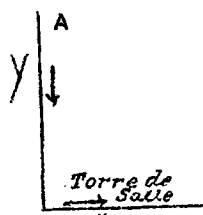
It has been calculated that over the whole area the depth of silt deposit per annum is 13 millimetres (1 inch).

The amount of silt collected between 1894—1899 was 570,000 c. metres, and as it has been estimated that 3,400,000 c. metres are still required : a period of 30 to 35 years will be necessary to complete the colmata.

The present basin contains 9 million c. metres, and as a high flood is calculated to give 20 million c. metres, it is intended to increase the area of the basin to take in nearly the whole.

Amount of raising.

(34) In order that the land may, after the completion of the colmata, drain properly towards Torre de Salle, the level to which the land must be raised at any particular point A from Torre de Salle of which the ordinates are X and Y with respect to that point, is given by the formula.



$$H = 0.95 + 0.05 X + 0.10 Y + 0.30.$$

0.95 being the height above sea level at the sea.

0.05 the maximum slope per thousand to main drain

0.10 do. do. do. secondary do.

0.30 the allowance for settlement.

Escape for clear water.

(35) There are two works for the discharge of the clear water at Cappezuolo.

One consists of 4 drop gates of 5.0 feet span revolving on the lower axis and raised or lowered by means of a travelling crane : the cill of the escape is 1.6 feet above mean sea level. By means of this escape the water can be gradually drawn off from the surface. The second escape has a span of 13 feet, with its cill $3\frac{1}{4}$ ft. below sea level, for the purpose of drawing off all the water in the basin.

The works at Torre del Sale for the same purpose are :—

(a) a similar escape to the one at Cappezuolo for drawing off the surface water, (b) an escape of 4 spans of 5.0 feet each for drawing off the water to the lowest level, (c) a weir made of wood and fascines 440 feet long for the discharge of excess water brought into the basin.

Duration of the colmata.

(36) The work has been in progress since 1828 and is not likely to be finished, according to the most recent estimate, until 1938 (about) so that 110 years in all will have been occupied in reclaiming this marsh. It must be noted here, however, that a certain area has already been completely raised and is now under cultivation—how much cannot be accurately ascertained.

Cost of improvement works in Tuscan Maremma to date.

From the initiation of the work up to 1905-06 a sum of Rs. 204,00,000 has been spent on land improvement works in the Tuscan Maremma.

BONIFICAZIONI AT RAVENNA.

Description of the improvement of lands in the valley to the north of Ravenna by means of silt—

(1) An excellent example of the system of the improvement of land by means of silt deposited on it is to be seen in the silt basin of the Lamone. Here the valleys of S. Egidio, Mezzano, Savarna, and S. Vitale have already been transformed, for the greater part, into most fertile land, *vide* Plate No. 9. During an extraordinary flood on 7th December 1839, the Lamone burst its right bank in the locality called Ammonite near Villa Santerno, the breach was 250 metres (820 feet) wide and the river channel below the breach was so damaged that it was found impossible to turn the river back into it without the execution of costly works.

Thus, by the force of circumstances as it were, commenced the improvement of the land now to be described.

(2) A commission assembled in 1840, to decide on a plan of action, recommended, since the idea of closing the breach could not be thought of, that the course of the waters should be inclosed between banks 650 feet apart. This is called on the plan "Allaciamento," or leading channel $2\frac{1}{2}$ miles in length, and by it the water is carried on to the low-lying lands. The whole area over which the waters are allowed to expand has been surrounded by a marginal bank.

Proposals of the first Commission.

(3) The Commission also settled to what height the levels within the basin should be raised. It fixed a height of 1.34 metres (4.4 feet) above the zero of the gauge at Porto Corsino, i.e., above mean sea-level, plus 0.10 per thousand, according to the distance of any point from the sea, measured on the shortest line of the drainage. The slope thus given to the lands allows of their readily draining on the completion of the colmata.

The Commission finally proposed, after the completion of the Colmata in this valley that the Lamone should be turned into the Podi Primaro, and that this latter should be diverted into the Reno upstream of S Albarto.

(4) In order to indemnify the proprietors of the lands within the basin they were allowed to cultivate rice, and were permitted to put up secondary little bunds for the protection of the tracts placed under rice cultivation. They were also allowed the summer water in the river for its irrigation, the just and equitable division of the water being left to the public authorities.

Rice cultivation within the basin of the Colmata.

(5) Plate No. 8 shows the state of the basin or silt tank as it was originally planned and carried out in 1840—44.

The drains Fiametto, Bendazza, Fossatone, Tuglia Nuevo carried away the clear water from the basin into a canal which discharged itself at Porto Corsini. No steps, however, were taken to direct the silt-laden water within the basin in such a manner as to properly silt it up, the basin was looked upon merely as a basin for the provisional expansion of the water of the river in the attempt to systematize the course of the Lamone, and not for the purpose of the improvement of the lands within it.

(6) This state of things was the cause of many complaints and led to the appointment of a second Commission in 1846, which laid down rules for the regular distribution of the turbid waters within the basin. These were followed with excellent results. Plan No. 9 shows the course of the "Allaciamento," the banks of which were gradually raised and extended. Minor channels were taken off from the main to carry the turbid water to outlying parts.

Proposals of the second Commission.

(7) One may here note that, when the marginal bank was constructed, there was a good deal of opposition on the part of the canal proprietors to the inclusion of lands, which though then low-lying with respect to the sea level were nevertheless under dry cultivation, because they were readily drained. They did not understand that when the Colmata was completed these lands would be too low to drain away to the sea and would therefore become swamps.

(8) In 1869 the raising of all the lands on the right bank of the Allaciamento up to the road of S. Albarto was completed and such lands were cut off from the rest.

Progress of the Colmata.

The area thus cut off was 4,310 acres out of a total 17,761 acres, besides which another 2,704 acres were nearly finished.

(9) In 1871, the diversion *Frata* was opened out, but it was soon recognized that, by raising the lands in this direction, a ridge would be formed which would cause difficulties with the future drainage of the

tract from W. to E. In 1898, therefore, the old breach was closed, the old bed of the Lamone brought into use again for another $2\frac{1}{2}$ miles and a new Allaciamento was opened.

With the addition of other lands which were added from time to time, the total area was increased by 1,976 acres. In 1898, 11,920, acres were completed and cut off. These lands were provided with a proper drainage system having their outlet in the main drain leading to Porto Corsini.

The area within which the waters could now expand became much restricted, and, after the construction of the new Allaciamento the following works had to be carried out :—

- (1) Marginal banks were carried on the left and right up to the road of S. Alberta.
- (2) To facilitate the flow of water across this road an opening spanned by a wooden bridge, 330 feet long, was opened and two other openings elsewhere made.
- (3) The section of the drain Fossatone, through which the clear water of the basin found its exit at Porto Corsini, was doubled, as also that of the drain Taglio, another outlet for the clear water.

(11) In order that the silting-up process should proceed regularly from up-stream downwards, two branch channels were opened up to the right and left of the mouth of the new Allaciamento.

These two branches remain open from October to April in each year—i.e., during the period of floods, of which there are 5 or 6 on the average.

For the remainder of the year they are closed by bunds to permit of rice cultivation, which is irrigated by means of special masonry heads in the river bank from the summer flow in the river, which is carried away to the sea in another channel.

(12) When the colmata of the lands near the mouth of the new Allaciamento has been completed the banks will be prolonged towards the road of S. Alberta, and the present banks will also have to be raised as the levels rise.

The basin will also have yet another 1,580 acres added to it.

(13) As the area of the basin will become more and more restricted it will soon be necessary to consider how the danger of inundation of the country and of the silting up of Porto Corsini can best be obviated.

This difficulty will probably be met by the diversion of the Lamone along its old bed with the Po di Primaro up-stream of S. Alberto: this however has not yet been definitely decided upon.

(14) This is a notable example of the ruin of the hills, through inconsiderate disafforestation becoming the good fortune of the plains.

(15) The surface of the Appenines, bare and uncultivated, is easily and rapidly eroded by the rainfall which finds its way into the Lamone, and its tributary the Marzeno, and through them into the Ravenna valley, which valley in ancient times was the defence of the city against barbaric hordes. To-day this valley, thanks to the silt-laden water of the rivers mentioned, is gradually being brought back to cultivation of a very high order.

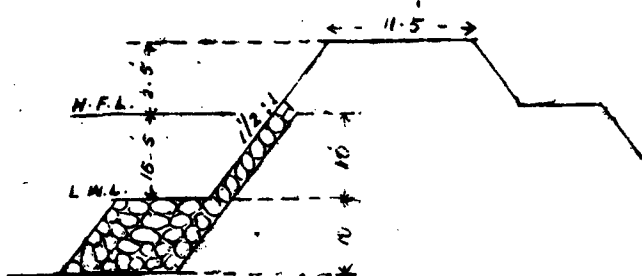
Flood discharge of the
Lamone.

(16) The Lamone has a drainage basin of 204 square miles, of which 183 square miles, or nearly 90 per cent., are in the mountains. The slope in the plains portion is 2·5 per thousand, and the flood discharge is 12,500 cusecs.

Embanked rivers.

(17) The river is highly embanked, as also are the Savio and other rivers of this tract.

In some cases the beds of these rivers are above the level of the country; generally, one may say, the water surface in the summer is at country level about, and flood level some 6 to 10 feet higher.



The marginal sketch gives a section of the bank of the Lamone where it has to be protected with stone pitching; across hollows, where the banks are specially high, a berm is generally added on the outside.

In spite of the high level at which these rivers run there is no percolation in the lands near the outside slopes, owing to the compact and argillaceous nature of the soil.

(18) The amount of silt carried in suspension by the waters in the Lamone is stated by the Engineers to be as follows:—

Average	...	3.5 c. metres per 100 c. metres of water.
Maximum	...	10 ditto ditto.
Though in one case was found	...	15 ditto ditto.

It must be remembered that this proportion has been arrived at by measuring the depth of silt deposit in cylindrical glasses containing, say, $\frac{1}{2}$ litre (0.88 feet) of turbid water: when deposited it will shrink owing to compression by about $\frac{1}{3}$.

(19) The fertility of the silt deposited by the Lamone is great, and constitutes an immense reservoir of nutrition, as it were, for plant life.

The following analyses were made by Signor Commandator Pasqui and Prof. Pasqualini in 1879 and 1877. The data show the mean results from 5 samples of silt from the Lamone: the mean results from 6 samples of the silt of the Savio are also added for the purpose of comparison.

It must be pointed out that there is a sensible difference in the quantity of clay and silica, according as to whether the samples were taken near or at some distance from the inlet; the first contains more silica than the second. It is also evident that the ingredients—clay or sand—will vary according to the greater or lesser intensity of the floods, and it must be noted that the Lamone runs down from the rocks of the Eocene period, while its tributary, the Marzeno, from the rocks of the Miocene period; and according as one or other is in flood, so does the nature of the silt, in the waters below their junction, vary.

(20) The following table shows how the water itself carries out the process of mechanical separation or levigation. The first sample of the silt of the Lamone was taken close to the stream entering the basin, the second at 1,200 feet to one side, the 3rd 2,600 feet, the 4th at 3,600 feet, the last at 4,800 feet.

			Samples.				
			I	II	III	IV	V
Sandy matter		...	20.40	19.04	16.80	15.30	15.00
Clayey do.	...	...	79.60	80.96	83.20	84.70	85.00
			100.00	100.00	100.00	100.00	100.00

Chemical analysis of the
silt of the Lamone and
and Savio.

(21) The analysis given does not, however, show the amount of nitrogen. The amount of phosphoric acid in the case of the Savio would in itself show the silt from that river to be the more fertile; but this fertility does not depend, as is well known, on the chemical analysis alone, but also on its physical and hygroscopic properties, the proportion in which the earthy ingredients are mixed, good drainage, thickness of culturable stratum. These together will form a soil of the highest fertility. The silt-deposited lands of the Lamone are in practice found to be superior to those of the Savio, Ronco, etc.

Prof Tornani, too, has made the following mechanical analysis of the Lamone silt which is in somewhat greater detail.

In 100 parts of earth dried in air :—

Coarse sand	...	Calcareous	...	8.292	} 29.505
		Silicious	...	20.768	
		Organic matter	...	0.444	
Fine sand	...	Calcareous	...	18.689	} 46.714
		Silicious	...	26.014	
		Organic matter	...	2.011	
		Clay	...	11.705	
		Humus	...	0.286	
Hygroscopic water	...		...	5.175	
Other soluble substances not determined	...		...	6.615	
Total				100.000	

Outturn of crops.

(22) The average outturn from these silt-deposited lands is as follows :—

Wheat quintals 18—22, 26—32 bushels per acre.

Beetroot quintals 400—500, 16—20 tons per acre.

Spanish hay quintals 90—100, 3½—4 ditto.

The predominant cultivation is thus approximately distributed :—

6/10 to 5/10 Artificial meadows of leguminous plants.

3.5/10 to 4.5/10 Wheat.

0.5/10 Beetroot.

(23) Large quantities of artificial manure are used. The mean consumption of Scoria Thomas, mineral super-phosphates and bone super-phosphates is 1.2 cwt. per acre.

(24) There is no doubt that a large amount of highly productive land has already been and is in course of being added to the country-side round Ravenna by means of the silt-laden waters of the Lamone and Savio. Production has increased, and greater production means more trade and greater employment of labour and capital. The hygienic results of the works both to Ravenna itself and the densely populated tract around it have been great.

Financial results of
colmata.

(25) The financial results of this work of colmata with the silt of the Lamone must now be examined.

The expenditure is as follows :—It includes the construction and maintenance of the banks of the Allaciamiento and of those round the basin, the construction and maintenance of the works, the opening of new channels for silting purposes and for drainage, compensation to proprietors—in fact everything which relates to the work under construction :—

				Rs.
1840-48	...	...	...	3,464 16
1849-71	...	...	...	10,82,214
1872-1903	...	...	...	18,74,790
Total				33,03,420

It is, however, necessary to consider what amount would have been spent on the maintenance only of the banks of the Lamone, which in any case must have been incurred.

This is calculated at Rs. 10,74,311 for a length of 14 miles. If this amount is deducted the total expenditure up to 1903 will be Rs. 22,29,109, or Rs. 187 about per acre, since the area completed is 11,920 acres. The cost per acre of the remaining 8,131 acres will be less, as the works for the most part have been completed.

(26) Before the initiation of the improvement the land values were Rs. 73 to 85 per acre; now lands in the valley with the prospect of being improved are worth Rs. 170, and lands already improved Rs. 267—291 per acre, the difference depending on the presence of habitations and drains.

The interest on the capital expenditure may be considered balanced by the return from the cultivation of rice which was rendered possible by the use of turbid waters.

We have therefore price of valley land Rs. 73 to 85 *plus* cost of improvement Rs. 187 = Rs. 260 to 272 (about) per acre, which is about the present value of land. The land is highly productive and yields a net revenue of Rs. 50 to 60 per acre, or even more, so that it can be asserted that the speculation has been successful one.

(27) Cost of earthwork in main drain, including excavation to 6½ feet below water level, Rs. 16·8 per thousand. Labourers get Rs. 1·6 per diem and will excavate 178 to 213 cubic feet per diem.

	Silt of the Lamone 1877.	Silt of the Lamone 1879.	Silt of the Savio 1877.	
<i>Mechanical analysis.</i>				
Coarse sand	17·31	16·344	15·44	
Clay and very fine sand ...	82·69	83·656	84·56	
Total ...	100·00	100·00	100·00	
<i>In 100 grains of earth dried at 110°C.</i>				
Soluble matter.	in distilled water at +15°			
	mineral ...	4,701	48,60	5,111
	organic ...	1,900	1,761	1,271
	in water saturated with car- bonic acid at +15°.			
	mineral ...	6,514	6,444	6,864
	organic ...	1,809	1,503	1,667
	in boiling hydro-chloric acid			
	mineral ...	29,041	16,841	29,803
	organic ...	1,518	1,709	1,489
	<i>In 100 grains of earth dried at 110°C.</i>			
Organic substance and water ...	2,770	3,275	2,869	
Matter soluble in boiling hydro- chloric acid.				
Oxide of calcium ...	11,136	11,853	10,822	
Oxide of potash ...	0,631	0,488	0,513	
Phosphoric anhydride ...	0,160	0,147	0,240	

IMPROVEMENT BY COLMATA OF THE RAGAZZENA HOLDING.

This is an interesting example of the improvement of land with the silt of the Savio river conducted by the proprietor himself, *vide* Plates Nos. 10, 11 and 12. The work of improvement was begun in 1870 and the land which required raising is shown in the Plate No. 11—the heights in this plan show the relative heights with reference to a fixed datum.

Colmata Channel.

(2) The channel has a bottom width of 3 metres (9·8 ft.) and a slope of 0·36 per 1,000 and is $1\frac{1}{4}$ miles in length to the further boundary of the property. The head has a single opening of 1·6 metres (5·3 ft.) with a height of 3·05 metre (10 ft.) up to the soffit of the arch.

The head is furnished with heavy wooden drop-gates working in wooden frames, one on the up-stream and one on the down-stream side. These gates are raised by means of levers working in an iron rack fixed to the back of the gate. Double gates are a necessary precaution, as the surface level of high floods in the river is several metres above the level of the country.

(3) At the commencement a marginal embankment was constructed all round the property, together with a ditch for the collection of the clear water which was connected with the main drain “Scolo consorziali.”

The land to be raised and improved was divided into 6 basins as follows.—

1.	Cassa stralciata ...	...	...	12½ acres.
2.	„ nuova ...	...	...	30 „
3.	„ di campi ...	...	...	75 „
4.	„ superiori ...	...	...	62½ „
5.	„ della casa ...	...	...	57½ „
6.	„ valle ...	...	...	67½ „
Total				305 acres.

Each basin was provided with a suitable ditch for carrying the turbid water and another for the drainage of the clear water after the silt has been deposited. The spaces between were divided in a suitable manner with low ridges, to facilitate the process of colmata and the cultivation of rice which is associated with it. Every year new basins are provided for the turbid water, whilst wet cultivation is carried on in the old ones. Rice is not put in the same ground more than two years in succession, in order to allow of another layer of silt being put on; by this process the land is gradually raised.

(4) In Plates Nos. 10 and 12 are shown the heights of the land, both before being raised, and also at the present time, with reference to the zero of the gauge at Porto Corsini. A comparison of these two will show that the maximum depth of deposit has been 5·0 feet.

(5) The Government laid down the following general rules for the bonifica of the Lamone basin. At the sea the land must be raised to a level of 1·34 metres (4·4 ft.) above the zero of the gauge *plus* 0·10 per 1,000 according to the distance measured on the shortest line on any point from the sea. By this rule $1·34 + \cdot 8 \times \cdot 10 = 2·14$ metres (7 ft.) would suffice here, but this has been already exceeded in several basins. As it is certain the land already raised will settle somewhat, it is not intended at present to relinquish the work. However, when the land has reached a height sufficient to afford easy drainage, the silt basins will be abandoned and only those maintained for wet cultivation which will require a small film of deposit annually.

(6) The little basin near the Ragazzena road has been cut off from the rest and planted with trees and vines, the others are worked in rotation by alternating wet cultivation with that of meadow and wheat.

(7) The system followed, in addition to the general raising of the land and the filling up of hollows, has given splendid results. Chemical manures are largely used. Chinese rice has given a return of 1 ton per acre, Rangoon rice 1·8 tons per acre. The meadow land has given a return of Rs. 65 per acre without taking into account the fact that 267 pounds of seed have been harvested, giving a total return of about Rs 97. Wheat has given as much as 40 bushels per acre.

The colmata has not only been a success financially, but has also resulted in the hygienic improvement of the locality. In the summer months irrigation is carried on with the clear water in the river.

(8) As soon as this holding is put into good order the channel will serve the lands beyond its boundaries.

(9) Owing to retrogression of levels in the bed of the Savio it became difficult to get in a proper supply, especially when the little summer floods occurred, which are particularly rich in silt.

Water was originally diverted into the head by means of a bund, but recently, a small weir has been built in the river below the head.

This is fitted with automatic gates which fall as soon as the flood water tops them.

(10) The system here followed in applying turbid water to the lands is exactly similar to the irrigation of rice fields in India. The compartments, or *kiaries* with *mendhs*, about 1 foot high are filled with the turbid water, which slowly passes from one compartment to another over the tops of the *mendhs* or through small gaps in them, and when the water is quite clear it runs off into the drains.

SECTION III.

COLMATA DI MONTE.

(1) The system of reclaiming ravines and stopping erosion in the hills is known as "Colmata di Monte."

This work has for its object the utilization of the force of the waters for the removal of the objectionable ruggedness, whether concave or convex, and for modifying or rendering the slopes more uniform.

The waters act in a double manner—

- (1) by eroding the projections or convexities and carrying away earth from them ;
- (2) by transporting and depositing the silt in the depressions or concavities.

(2) The most perfect system of colmata di monte yet devised is that worked out by Agostino Testaferata, who was the agent on the estate of the Marquis Cosimo Ridolfi at Mileto from 1793 to his death in 1822.

(3) This estate (some 1,500 acres in extent) was visited by us for the purpose of studying this system of colmata, for it is still in progress here and has, therefore, been going on for nearly 100 years.

(4) I was very much struck with the really marvellous results obtained with the simple means adopted. The value of the estate has risen immensely owing to the work which has already been carried out.

(5) In order to explain the system I will first give a general account of it, together with an example which has been taken from "La Sistemazione e lo scolo delle acque nei terreni in Collina" by Dott M. Conti.

This describes not only the work of colmata in the ravines in a general way, but also the system of dealing with the slopes between these ravines by the method which is called "La Sistemazione a Spina" which follows the former.

(6) I will then give an account of a portion of the work carried out at Mileto, which has been taken from "Le Coltivazione di Poggio," by Luigi Ridolfi.

This description relates more particularly to the work of colmata in the ravines themselves.

(7) The following account of the systemization "a spina" is taken from Dott M. Conti's work on "The systemization and drainage of water in lands situated in the hills."

Valuable matter carried away by drainage water.

(8) In order to give some idea of the valuable matter carried away by drainage water and the damage this latter actually causes, the following chemical analyses are given, both of the soil of hills of a somewhat argillaceous character and of the silt carried away by the streams running off them during a period of heavy rainfall.

	Soil in the hills.	Soil carried away.
Vegetable matter	0.2 to 0.8 per cent. ...	1.3 to 1.6 per cent.
Clay	40 to 70 „ ...	70 to 80 „
Sand	30 to 60 „ ...	20 to 30 „
Lime (constituting 70 per cent. of the sand).	35 to 40 „ ...	20 to 25 „

(9) In 100 parts of fine soil dried in the air.

	Soil in the hills.	Soil carried away.
Moisture	3 to 5 per cent.	4.5 to 7 per cent.
Loss from calcination (deducting the moisture).	2.7 to 5.5 „ ...	4.5 to 8 „
Organic carbon	0.4 to 0.8 „ ...	4.5 to 8 „
Equivalent amount of humus with 58 per cent. of carbon.	0.69 to 1.37 „ ...	2.84 to 4.25 „

(10) In 1000 parts of fine soil dried in air.

	Soil in the hills.	Soil carried away.
Organic and inorganic nitrogen ...	0.9 to 1.12 ‰ ...	1.26 to 1.68 ‰
Phosphorus anhydride	0.6 to 1.2 „ ...	1.6 to 2.1 „
Oxide of potassium	4.4 to 6.9 „ ...	6.4 to 8.3 „

(11) The above analyses are the mean results of several samples in each case and are worthy of examination. The land in those hills which is poor in matter useful for plants and very poor in humus is so washed by the rainfall that, in the course of time, it becomes absolutely deprived of those elements which are the prime causes of the fertility of the soil.

(12) The rainfall in descending from the hills to the plain tends to collect in the more depressed parts of their surface and is the cause of damage, because here, more than anywhere else, the water begins to cut channels which, in the course of time, become ravines. The effect is more rapid when the land has not time to absorb the rainfall in sufficient

quantity to confront the drought of the warm season. The evil results are less felt in lands which are light and capable of absorbing a portion of the rainfall.

In general the hills in Italy are composed chiefly of clayey earth which has little permeability.

(13) Professor Sisteni stated, when discussing the value of the silt carried by the Arno, that the analysis shows that one quintal of sediment left by the river Arno contains, when dried in air, about as much azote (organic and inorganic nitrogen) potash and phosphoric acid as would be obtained in half the amount of stable manure.

It is certain, he writes, that an *irrigation* made at due time and in a favourable locality can carry on to the ground a quantity of fertilizing elements, comparable with those which would be supplied by the purchase of matured stable manure, independently of the raising of the soil and of the advantages of controlling drainage.

(14) The following analyses are taken from Durand Claye's Agricultural Treatise :—

			River Nile.		River Durance.
Azote	...	...	0.17	} 16.10	0.07 to 0.13
Combustible matter	...	...	15.90		0.56 to 8.27
Lime	...	...	1.34	} 83.90	20.30 to 29.95
Aluminum clay and ferric protoxide.	and	...	22.82		4.25 to 5.65
Phosphoric acid	..	...	0.42	} 93.37 to 91.60.	
Other matters	...	...	59.32		

The Durance alone is estimated to lose in the sea more than 14,000 tons of azote, equal to about 35 million quintals of stable manure.

(15) The difference between colmata in the plains and in the hills is that, in the former case, the silt already collected in the stream and torrents can be made use of, while in the latter case the rainfall on the surface of the hills only can be used.

(16) Water acts in a twofold manner—that is to say, on the one hand it erodes the prominences and so becomes rich in earthy matter, and on the other hand it deposits this in such a way as to level up the depressions.

(17) It will be at once understood that the possibility of putting into practice the work of "Colmata di Monte" depends largely on the physical and mechanical nature of the soil.

It is possible, in fact, in hills of the tertiary formation (clay variously coloured and stratified with yellow sand) and in general everywhere where there is a soil which can be eroded and carried away by running water to be deposited again in more or less minute particles, as soon as the water moderates or loses its velocity entirely.

(18) A general practical rule in carrying out "Colmata di Monte" is the following ; that, when the slopes have been excessively eroded by the action of the water, one must commence by consolidating the base :—*hence colmata must always be begun from the base.*

(19) The work of colmata cannot be considered as a thing by itself but in relation to the systemization "a spina" which must follow it.

It is not possible, therefore, to treat the two arguments separately, as they are so intimately connected.

The work of colmata can be initiated also some years before the tracing of the systemization "a spina" and especially where there are large hollows to silt up or there are hindrances such as plantations.

This work of colmata must be carried out, however, in such a way as to render a better tracing of the systemization "a spina" possible.

(20) It will always be assumed in the following description that a start will be made with lands already under cultivation, presenting however, either naturally or on account of a bad system of working the land, well marked superficial irregularities which have destroyed the surface and have rendered agricultural operations and communications difficult.

Study preparatory to the construction of the basins of colmata.

(21) It must be noted before proceeding further that, both on the initiation and during the progress of the work, great care and circumspection are required, and these can only be gained by practice and long experience.

In addition to the plans, and an intimate knowledge of the place where the work is to be done, a well trained and experienced eye, with acute powers of observation, are necessary in order to be able to foresee at the outset the best way to carry out the systemization from beginning to end.

A contour plan of the land will be of great assistance. It should be on a scale of not less than $\frac{1}{2000}$ with contours at every metre difference in level.

(22) The waters which, during the systemization, must act so as to erode and deposit earth must, when the work is completed, do neither.

As the work of settlement proceeds their action must be moderated, so that when it is finished they can not only no longer alter the surface, but even run so as to preserve it.

Arrangement and disposition of the work of colmata.

(23) The way in which the contours run will give a clear idea of the superficial configuration of the hill.

In following them with the eye one can distinguish the great changes, in this connection which must, without fail, be maintained, and also all the secondary changes, which much must be removed by the judicious work of colmata.

Difference between colmata and colmatelle.

(24) Here the difference between colmata and colmatelle must be explained. The former is the work of removing the more pronounced irregularities, the latter the work of filling up the little valleys or slight depressions.

Plate 13, Figure 1 will render this clearer. Colmata is the work of filling up the marked depressions C.C. and colmatelle the work of filling up the slight depressions c.c. This latter will be referred to in treating of the systemization "a spina" because it is one of its principal advantages.

Construction of the basin of colmata.

(25) The basins of colmata are simply formed by bunds placed for the purpose of breddling the course of the water.—Plate 13, Figure 2. These must be so situated as to correspond respectively to one of the circulating ditches of the systemization "a spina" whenever this is carried out; and more precisely each of them must be placed immediately above the profile of such a ditch to avoid the risk of the bund being breached.

The basin and the bund together form the system of colmata.

(26) The dimensions of the bund must not be cut too fine, otherwise a breach may occur. The earth must be placed in layers and well consolidated, and the bund should be well let into the hill sides.

The bund should be a low one to start with, and raised gradually by successive layers as the silt is deposited in the basin at its rear.

(27) Each basin must have an inlet and outlet; the first for admitting the turbid water, and the second for letting out the clear water, which would otherwise flow over the bund. Water passes from one basin to the other, the inlet and outlet being generally arranged on opposite sides. The arms of the ditches, carrying water and called regulators, are directed down the shoulders in order to scour away such prominences. The silt-carrying ditches require to be cleaned out from time to time.

The water will run from one basin to another in a zig-zag course and do its work in a more or less automatic manner.

(28) Once the colmata has been rationally constructed, but little annual maintenance of the basins of the colmata, of the colmatelle or of the overflow weirs, etc., will be required in comparison with the great work, which has been performed by them in such an economical manner.

Maintenance of the work
of colmata.

(29) The silt carried into the basins tends to transform them into a flight of steps as it were, while uniform planes are required.

Every year, when convenient, these basins should be cleared. This is generally done in the summer time. The work-people then throw part of the silt on the banks in order to raise them and part on the downstream toes to strengthen them.

(30) In order to make greater use of the power of the water, which runs down the hill, one sometimes has recourse to the construction of a small lake, and as far up the hill as possible wherever a suitable site can be found. This lake will collect the rainfall of the hill above it. It is easy to perceive that on the score of economy one must choose a hollow in the land. This hollow will be encircled on its lower side by a strong bund provided with several outlets, so that a good volume of water can be diverted in any direction for the purpose of eroding the prominences of the soil—the depression, of course, in which the lake is formed also, in the course of time becomes filled with silt.

(31) In other cases where the lie of ground is not suitable for the construction of a lake a contour ditch is made for the same purpose.

(32) The work of colmata here described tends to remove the greater irregularities of the surface, which, more than anything else, hinder the tracing of the systemization "a spina."

In establishing a systemization "a spina" certain conditions must constantly be satisfied, without which it will not be possible to obtain all the advantages which the system possesses. The various faces, of which a hill is formed, must, above all, present a regular surface: if this is not the case, one must study, together with the project for systemization, that relating to the arrangement of the surface.

The tracing of a systemi-
zation "a spina."

It is necessary to obtain such a regular surface by means of the work of colmata in order to form compartments of sufficient width and regular in form adapted to the better disposition of the trees and in order to render agricultural operations with animals both possible and easy.

(33) Access to the various parts of the farms for both men and animals must be easy; a good net-work of farm roads is therefore required.

(34) From the plan showing contours at every metre of level it will be possible to understand the lie of the surface and to draw the lines called *lines of the points of spina*.

These are drawn along the valleys and prominences and join therefore all those points on the curve where it changes its direction.

The tracing of the ditches will be easy from the fact that they will be delineated by the lines of the points of spina. The ditches must be parallel to each other, and at a distance representing the width to be given to the compartments.

This width depends on the inclination of the hill and should not be less than 12 metres (40 feet) or more than 20 metres (65 feet).

It will, however, be better to regulate the width on the following consideration, viz., that the difference of level between two adjacent ditches should be from 3 to 4 metres (10 to 13 feet) according to the nature of the land in order to avoid either an excessive accumulation or an excessive run off of the rainfall from the various strips of land and in order not to have too high shoulders for the terraces which may afterwards be made.

(35) The slopes and the dimensions to be assigned to the ditches must be fixed in accordance with the nature of the soil and the quantity of rainfall to be got rid of.

The slopes should be between 0.5 and 1.0 per cent. and the dimensions of the ditch as follows :—

Depth 1.0 to 1.3 feet, width at base 1.0 to 1.3 feet and the width at top 1.6 to 1.8 feet. It seems hardly necessary to say that the larger dimensions are required for more compact earth and *vice versa*; and that these dimensions must be increased gradually towards the foot of the hill because a greater quantity of water is here collected.

(36) In tracing the lines of the systemization it may happen that the lines of the points of spina remain parallel. In this case ditches of equal length will result, and compartments easy to be planted in regular order and easy to be worked.

When the inclination of the land is uniform the compartments will be of equal width, but when its inclination varies the distance between the ditches must vary to maintain between them the limit of difference of level noted above.

On the completion of the tracing of the ditches the land is found to be systematized "a spina."

(37) When the contour curves show great variation relatively, that is to say, with the lines of the points of spina, the ditches are angulated. Now, when the angle is towards the person looking at it, it is called an *open spina*, and when its vertex is presented it is called a *closed spina*, vide Plate 14, Figure 1, which illustrates this.

(38) After collecting the water in these circulating ditches the best method to get rid of it from the fields and send it to the plains must be studied.

The ditches, which connect the circulating ditches, must be traced directly down the slope, but they cannot always be permitted to have an erosive action on its surface, for, when this latter is deprived of prominences to be cut away, or when it is excessively steep, artificial means will be needed to render the course of the water as little harmful as possible.

These connecting ditches must then either be taken obliquely down the slope, or furnished with banks or bridles from tract to tract, vide Plate 14, Figure 2, or in more unfavourable cases they must be pitched and provided with some little wells or cisterns to eliminate the force of the water in its descent.

(39) In commencing the study of the systemization it has already been remarked that it is necessary to design a good distribution of farm roads. Such roads, if judiciously laid out, greatly help the work of cultivation, as they give ready access to the various fields.

The farm road must not, however, be opened in the folds of the hills, that is, where the spina is open, because the water will run down there (as in the connecting ditches) into the cultivation causing erosion and damage.

The above rule must be strictly observed: but where, for special reasons, the cultivator must have a foot-path along a depression, he can always lessen the bad effect of doing so by reducing to a minimum the

quantity of water which can flow away along it. The better course for the farm foot-path on the hills is, however, that offered by the lines of the points of spina traced on the prominences.

(40) Here ends the description of the work which can be laid down on the plan. In order to proceed to lay it out on the ground no special rules are required, only a little practice and a certain confidence with the ordinary instruments in use are necessary in order to be able to transfer all the particulars from the plan to the ground.

Laying out the systemization on the ground.

The corresponding position of the lines of the points of spina must first of all be laid down. The distribution of the contour ditches, their direction, and their distance apart is then marked out with stakes, and finally the position assigned to the farm roads and to the collecting ditches. When this is done all that remains is the manual work of excavating the ditches, according to the form and dimensions previously laid down.

(41) It has been assumed that the various straight lengths of the ditches have a uniform slope of about 0.5 to 1.0 per cent., so that the water can freely run from one extremity to another. But this is not commonly the case. In desiring to trace ditches of some length, numerous impediments, caused by the irregularity of the surface, are found along the alignment.

Work of colmata.

From a cursory examination of Plate 14, Figure 3, it will be seen that when one wishes to trace ditches of a given slope between the two lines of the points of spina $a\ b$ & $a'\ b'$ one must make them follow the tortuous lines of a contour. If the ditches are given a straight line course their slopes will be variable, and water will tend to collect in the depressions. For example, the water which should go from a to a' will not be able to do so because of the prominences *r. s. t.*, and will tend to run along the depressions because it is hindered from rising from one part to the other.

The work of colmata must aim at removing such irregularities. Little banks on the downstream side of the single ditches are constructed corresponding to the points $c\ c'\ c''$ and banks of a more solid description corresponding to the points $c\ c'\ c''$. We have then in $c\ c'\ c''$ colmatelle and in $c'\ c''\ c''$ colmata with a true system of silt basins.

With regard to these last one must follow the rules already laid down, but with regard to the colmatelle there is but little to do, and that not very costly. For the construction of the little banks the earth excavated in the circulating ditches is used; the height will be limited at the start and will be increased in successive layers afterwards.

The work of maintenance reduces itself entirely to good regulation and to the best manner of utilizing the water coming into the basins.

In fact, the water in passing from one to another of the basins must be made to run across the prominences (in this case *r. s. t.*) in order to carry away earth from them to the depressions.

Plates 15 and 16 will give a clear idea of the simultaneous work of systemization and colmata.

They show two hill-sides, one facing south and the other north of the same hill.

The work of systemization with the tracing of the circulating ditches, the silting ditches and the collecting ditches are shown, also the construction of solid bunds for the colmata and more modest ones for the colmatelle.

Plate 17 is reproduced from a photograph taken of the farm of the Agricultural School of Macerata, and represents the disposition of the colmatelle along the circulating ditches "a spina."

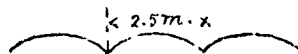
Plate 16 represents in fact the hilly fold of Plate 15 after the work of colmata has been finished.

(42) A particular example is now given, and the land chosen is that represented in Plate 19. The contours, shown at 3.6 metres apart, instead of 1 metre to avoid confusing the plan, will give a full and clear idea of the surface. On the top of the hill is the farm house.

It will be noticed that on the east and west sides there are deep ravines in which all the water from the farm is collected.

(43) This land is worked on the system of "ritto-chino," as represented in Plates 20 and 21.

The earth is furrowed in the sense of its greatest slope and divided into ridges (porche) 2 to 5 metres wide, *vide* marginal sketch.



The water much sub-divided runs along the little ditches separating the various ridges, but when these are of considerable length the water acquires an excessive velocity and causes erosion.

The furrows tend to diminish the damage which will evidently result from this erosion, and to discharge the water in the direction indicated by the arrows.

The damage caused by this system of working is evident. The land is placed under cultivation, but owing to its irregularity a good part of the surface cannot be cultivated and its productivity is very low, owing to the washing it undergoes from the water, so that the substitution of another system on the lines which will now be described will be an economy.

(44) Given a very irregular tract of land, the tracing of a systemization a spina cannot be carried out without, at the same time, solving the important problem of the regularization of the surface by means of "Colmata di Monte."

The physical mechanical nature of the land lends itself quite well for the execution of such work.

(45) It has been said elsewhere that the construction of the basins of colmata is the first and also the more interesting step in the prosecution of the systemization.

In the present case the lie of the land is such as to permit and render relatively easy the work of colmata.

The disposition of the land placed under colmata is represented in Plate 22.

There are two principal systems of silt basins: the waters are collected in them, and their course is regulated by means of channels which guide them to erode the higher and nearer parts.

The location of these channels is liable to be changed from year to year. Other little basins (colmatelle) are made here and there along the circulating ditches in the slight depressions. These colmatelle communicate with one another and with the principal basins by means of a series of little silting ditches.

(46) The earth necessary for the colmata will be furnished by the erosion of the more elevated parts of the soil, and these are shown in good relief by the contour: also to a large extent by the turbid water of the ditch A. B., which carries the water which drains off the lands above.

In a sufficiently elevated depression in the hill, and in such a position to allow of its collecting a copious supply of the rainfall, the little lake is made whose function has already been explained.

The earth used in the construction of the banks will be that coming from the excavation of the silting ditches, and eventually that brought down from the nearest prominences.

The alignment of the systemization a spina when the work is completed is shown in Plate 23.

Figure 32 and the section show the arrangement of the land when the work is completed. It should be noted that the sections and plans are drawn to different scales in order to show the differences of level more clearly.

(47) The reasons why some authorities do not consider the systemization a spina to afford cultivation all the character necessary to render it rational must now be stated. They are as follows :—

(a) The carrying away of the earthy matter will be but little diminished by this system.

(b) The water, running off one of the strips of land (*lenza*), can erode and carry away a good deal of earthy matter before reaching the ditch made to receive it.

This earthy matter is collected in the ditches to be used for laying at the roots of the trees, but in the period of specially heavy rainfall a part of it, and precisely the better part, is in some way inevitably lost.

In the systemization a spina, the lines of trees can be put above or below the ditches. If they are placed above the ditch, in addition to its being difficult to lay the earth at their roots, the trees are exposed to excessive drought in the summer time : if below it is not so difficult, but the slope of a single strip is gradually increased, because it is raised on the up-stream side and subject to continuous erosion on the down-stream side.

However, this last objection loses somewhat of its force when it is considered that the work of the plough annually reduces to some extent this raising and tends to establish some sort of equilibrium.

(48) One of the objects which any systemization must aim at is that of allowing the land to absorb a large part of the rain falling on it, in order to form a reservoir of moisture, as it were, for the dry season.

Whether this object is reached with the systemization a spina as described above is doubted by some.

The water still runs off the surface with too much velocity and the absorption of the rainfall cannot be much increased, especially when the land is somewhat compact.

It is only in the land in proximity to the collecting ditches that the absorption is increased, because the water runs in them with less velocity.

(49) In order to find a remedy for the above drawback, to carry out, that is to say, a rational system of agriculture, Cuppari counsels the adoption of the system of terracing the land.

(50) The systemization a spina from its nature is destined to be transitory for the reason that the cross ploughing of the compartments tends to gradually diminish the slope of the land until at last true and proper banks are formed.

(51) It is not every one, however, who takes it into his head to follow this plan.

Some oppose the formation of terraces and do so in this way : after the land has been ploughed the earth of the first furrow of the strip *a* is shovelled into the void left by the last furrow of the strip *b*, *vide* marginal sketch.



The systemization a spina is transitory.

Thus, although the slope of the hill is maintained unchanged, the surface nevertheless is lowered from always losing earth on the up-stream side—this a serious fact and not without harmful consequences.

(52) Conti, however, says that those who like himself have learned to recognize how very necessary it is to decrease the slope in order to preserve the land in the best condition possible, must consider the systemization a spina to be altogether transitory and leading to the gradual terracing of the slopes.

Even if this is not done it will nevertheless be recognised, he says, to be of much utility and to possess many advantages.

(53) But even if it is understood that this may follow, this system is still opposed by some since.

Terraces reduce the productive surface too much.

This is true, but if one considers that the production on a horizontal plane is greater than on an inclined plane of the same area, and if the grass on the slope is taken into account, one sees how little loss there is in this respect.

(54) Terraces are found fault with because they leave the soil too much exposed to drought on account of the evaporation from the slopes.

(55) In regard to this Conti says, "we will consider with Cuppari the following two facts :—

First, even if the slopes of the terraces evaporate more in summer, they have accumulated in the spring, a great reservoir of moisture in the subsoil : secondly, that in the case of inclined surfaces especially, the superficial roots have force, depth and direction different in comparison to the lower roots."

(56) It is thought that the grassy slopes will immediately grow weeds on ceasing to yield any other product, and that they will fall into ruin by the continual scraping away of the base and by the piling up of the earth on their crests.

This objection, however, while it has some force in the case of walled terraces, is quite erroneous, seeing that annual maintenance and repairs are required as much in the case of terraces as in the case of the systemization a spina, if the work is not to be compromised.

(57) The objection, which can more fairly be urged against the system of terracing, is the expenditure involved, which renders it only economically possible in those places where especially intense cultivation is followed.

Conti agrees with Cuppari that enterprising cultivation in the hills must be preceded by a system of terraces.

The system of directly terracing the land is hence only possible in rare cases ; but it is not this kind of terracing that is here being treated of, and one wishes to think of a more economical, though not so rapid a method, of arriving at the same result. Such a means, Conti considers, to be at one's disposal if one thinks that by the system of cross working the systemization a spina can be gradually transformed into a true and proper system of terraces.

(58) When the slope of the soil does not exceed 10 or even 12 per cent. on lands sufficiently permeable, the systemization a spina can solve many of the inconveniences. In such cases it can be maintained as such, and in order to do so the method as described in paragraph 51, must be followed.

(59) When, on the other hand, the slope of the land exceeds the above limits after the systemization "a spina" has been completed, one must try to reduce the excessive slope by means of gradually terracing with the annual work of the plough. This ploughing is hence destined

sooner or later to accomplish the terracing in the most economical manner possible: nor is it clear why one should not try to reduce the slope from the moment that it seems possible, in order to obtain in the hills all the advantages in the plains by excluding the disadvantages which the latter present.

Conti sums up by saying if the systemization a spina be considered transitory, the inconveniences which it can give place to are destined to gradually disappear as it approximates, owing to the annual agricultural operations, more and more to a perfect system of terraces.

(60) The following description of the Colmata di Monte is taken from Marquis Luigi Ridolfi's work on cultivation in the hills.

(61) The plan, *vide* Plate 24, represents a valley on his estate at Mileto.

The difference of level between the higher and lower portion of the valley is 140 metres and the top is 190 metres above sea level. Contours are shown at every 5 metres where the valley is steep, and at every 25 metres where less so.

A farm road runs along the southern crest of the basin and on it are shown the contour heights. Another road takes off at *A*, crosses the valley on the bank *a a'* and rises again to *A'* along a spur of the hills which divides the basin into two.

Other less extensive prominences along the ridge *C₁ C₂ C₃* separate two great central depressions which may be called ravines. These ravines have lost a large part of their forbidding aspect due to the erosion of the soil, so that they are now more or less level land.

(62) At the outset one must consider how to lay out a system of ditches and dispose the various slopes in a proper manner; and this must be done, not only where the work is likely to succeed best, but for the whole surface.

One must proceed to raise the bottom levels and to depress the prominences by utilizing the drainage water to erode the latter to fill up the former.

(63) The work was commenced with the road bank *a a'*, and this in the course of time was repeatedly raised and, as a consequence, also lengthened.

The rainfall over the whole basin above this bank and between the two roads *a' A'* and *A A''* was impounded at the back of this bank, up to a height determined by the overflow weir established on one of the flanks; this weir was shifted from time to time according to the deposit of the silt in the basin above.

(64) Where the bank had been raised sufficiently, and so much so that it was not likely to make the lands below cold, a second bank *b b'* parallel to the first was then constructed to form a new silting basin. This bank was similarly raised and prolonged from time to time and provided with an overflow weir: the plan shows it on the right flank where it was actually made, and where it was found convenient to allow it to remain.

(65) The water which flows over this second weir is, by means of suitable ditches, turned and distributed among those parallel ditches which in the meantime have been made to divide the fields in the first silted-up basin. The annual clearance of these ditches tends to the gradual raising of these same fields which are by now large enough for cultivation.

The water from these field ditches runs into a collecting ditch, which is given an angular course along the other side of the valley.

(66) The water in the collecting ditch runs just above the bank *a a'*, which it crosses by a masonry bridge together with the water which comes down the ditch *b' a'*.

(67) Here, in leaving off to follow and describe the subsequent proceedings with the colmata above, it may be explained that the same system was followed above the bank $b\ b'$ as below it.

(68) When the colmata was sufficiently advanced above the bank $b\ b'$, a third bank $C\ C, C_{\text{II}}$ was made.

This was given a kink in order to close at right angles each of the ravines into which the valley is divided.

The same procedure as already described was followed in this case too.

The plan shows the overflow weir finally established at C'' but in order that the water should not run directly and therefore rapidly towards the overflow weir of the bank $b\ b'$ at b' it is diverted across the valley and then follows an angular course along the base of the hill on that side.

(69) The agricultural ditches of the second silting basin have their heads in this ditch and divide among themselves the water running in it, which is once more turned into a collecting ditch which leads to b' and from this point it is carried by the ditch $b'\ a'$ to be again divided between the agricultural ditches of the first silting basin.

(70) In this way the progressive raising of these two basins proceeds by means of the annual clearance of these agricultural ditches, the silt from which is thrown on the down-stream edge of each ditch and then spread over the fields at the time they are ploughed over.

(71) Above the bund $C\ C, C_{\text{II}}$ are two hollows which are now closed by equidistant and parallel banks; these are gradually raised as the basins above them get silted up.

(72) Silty water is conducted to these basins by various channels opened on the sides of the hills when the agricultural work in the field is going on.

In aligning such channels one has to strive at one and the same time to preserve any sowing that has been done, and to direct the water with more or less velocity, according to the inclination of the various tracts, to carry earth to those parts where it will serve to improve the lie of the land. When, owing to successive working the prominences are levelled down, the drainage water is diverted along another course.

(73) On account of the rapid rise of the hill and the bottom of the ravines above the bank $C\ C, C_{\text{II}}$ extended tracts of colmata (to be divided into sloping fields) cannot be formed. It will also be a long time before the joint work of agricultural labour and colmata in depressing the prominences or crests $C_1\ C_2\ C_3\ C_4$ and in raising the bottom of the ravines, will admit of fields being formed on the slopes of the hills by means of angularly aligned ditches (systemization a spina). These ditches have been shown on the plan on the left of the road $a'\ A'$ in a tentative manner for the purpose of showing how they may probably be aligned, although it may be found necessary to alter them in practice afterwards.

(74) Continuing now the description of the proceedings which are always in action. In spite of the long meanderings and the partial stagnation of the water in the above described colmata of the hills, it always carries off a certain amount of matter which it does not deposit, unless brought to a state of absolute rest. This then is the advantage of never desisting from trying, in the lower lying valleys also, to decrease to the utmost the velocity of the water by holding up as much of it as possible in large and ample ditches, provided that this proceeding does not tend to render the land cold.

(75) The water which at the time of rain is not held up in the basin and in the silting ditches above the bank $a\ a'$ crosses the latter

by a little bridge left open on its flank, and then is turned into a ditch which runs below the same bank, and then under the road which, on turning to the right, separates the valley from the hill above.

(76) This ditch on the plan appears to stop at the point *E*. This is because if it were carried on, it would have too great a slope as the line of levels show. The water, however, contained in the ditch is divided up among the numerous agricultural ditches and is collected again on the opposite side, reuniting with the water which is separately sent down along the boundary of the wood called Commune, from the other valley.

(77) In these cross ditches, which have a gentle slope, the velocity of the water slackens and the water is partially held up in them by means of little bunds over the tops of which only the water runs into the collecting ditch.

Thus in the course of years a considerable deposit of silt takes place. This is dug out every summer and thrown on the down-stream of each ditch along which the lines of vines and poplars are placed.

(78) Referring to the plan and following the contour of 55 metres, it can be seen how the said collecting ditch comes to be carried higher and higher up on the side of the valley, when, owing to the gradual raising of the bottom of the valley and the consequent lengthening of the fields and cross ditches, it can no longer fulfil its office: the same cross ditch can always be commanded by the discharge ditch of the higher colmata.

(79) It can be quite well foreseen that the said discharge ditch may become one day a collecting ditch if the course of the water in the cross ditches of the valley is inverted, when the water from the colmata above is turned somewhat higher up into a new silting ditch (colmatore) to be opened up on the opposite side. Into this latter the water from above a new road bank will have to be discharged, this bank being constructed between α' *A'* and the above mentioned wood, with its crest about 60 metres above sea level, thus closing the valley, in the bottom of which is the ravine which collects the water, and so forming a new silting basin.

(80) It must be borne in mind, with reference to the possibility of this last, that the proposed procedure here treated of can only be roughly sketched out and that, in order to put it into practice, it is necessary to foresee and prepare for a long time beforehand the course to be followed. For the portion already undertaken, the actual position of the silting ditches secures that they will perform their functions properly for a sufficiently long space of time: this work of colmata divided, as it is, among a considerable number of ditches, must be necessarily slow, especially as this part of the valley is no small one.

(81) It must now be explained how the same work is prosecuted lower down.

The lower contour lines show that the bottom of the non-wooded valley may be naturally higher on the left side than on the right in regard to its longitudinal slope.

If, however, the water brought to point *E* of the collecting ditch (of which mention has been made above) should have continued its course on the same side of the valley, it would have risen but little in the cross ditches of the fields and, hence, it would not have been possible to have used them for forming fresh deposits in them.

For this reason it was considered expedient to turn the said collecting ditch from *E* across the valley in order to carry it past the opposite sides of the fields. In this way the water running in it could be divided in the usual way between different cross field ditches, which were led away from it, and these latter, as usual, will all find an outlet in another collecting ditch opened in continuation of the one above. On

the plan the lower ditch appears to start afresh at *E*, but in reality the deviation of the course of the water is here obtained by means of a solid bund, or weir, over which the water flows on occasions of extraordinarily copious rainfall only.

The ditch, which has here become a silting ditch, is continued on the left side of the valley only up to *G*: at *G* it turns again across the valley, for which reason it does not join the water of the brook Fontaccia, which has been diverted under the wooded hill Tagliatella and brought to *H* in order to command with its water the cross ditches of the valley which take off from it.

The two watercourses which collect all the water of the superior branches of the same valley traverse it a short distance apart, and unite as one, which henceforward, under the name of the brook of the Maremmana keeps along the right side of the larger lower valley until this opens out in the plain of the River Elsa, into which it flows. All of the water, however, does not flow *directly* into the Elsa, because every cross ditch takes off a portion of the water to be returned again lower down: in this way the water deposits its silt, which is annually dug out and then thrown or spread over the fields.

(82) One has an example of this in the lower tract, which is shown on the plan.

The cross ditches which divide the lower portion of the valley into fields are seen to be commanded by the brook and, since the water in this tract will not be able to reach right up to the footpath which separates the tract from the hill above, a collecting ditch *I K*, is opened somewhat lower down for the purpose of collecting the water and conducting it where necessary.

SECTION IV.

Conclusions to be drawn from the Italian Works and an examination as to how far they are applicable to India.

(1) The methods pursued in Italy for the utilization of silt for the reclamation of swamps and marshes, which have been described in Section II of this Report, will not be unfamiliar to Irrigation Engineers in this country who have had to deal with silt traps.

(2) Silting operations in this country, however, have been for the most part directed to the strengthening of the banks of a canal where they happen to be in high embankment or in bad soil, and in order to avoid the digging of formidable borrow-pits, either inside or outside the canal banks.

A very economical and simple method known as the *system of internal silting* has been evolved which is now widely followed in the case of new canals and distributaries.

(3) The earliest attempts made with this object in these Provinces were on what is known as the *in-and-out system*; and although the results were successful, the operations were both protracted and costly, and would afford no guide as to the cost of the reclamation of a considerable area.

(4) It is only within the last few years that attempts in these Provinces have been made to utilize the silt carried in our canals for the sole purpose of reclamation of any considerable area.

These works are still in operation, but I hope to give in the appendix a note as to their probable cost, and what return they are likely to give on the estimated expenditure.

(5) The chief thing noticeable in regard to these reclamation works in Italy is the large scale on which they are carried out, and this is only possible where the physical conditions of the country are as favourable as they are in Italy, and where the rivers carry such an enormous volume of fertilizing silt.

Owing to these favourable conditions the engineering works are of a comparatively simple character. There, it is not a difficult matter to divert the turbid waters of the numerous torrents running down from the Appenines into the marshes and swamps, which are found in so many places near their mouths along the sea coast.

(6) Even where the whole torrent cannot be bodily turned into the marsh, a short diversion canal only, as a rule, is required, owing to the high slope of the alluvial plains between the foot of the hills and the sea. The soil, too, is of such a character as to admit of such canals being carried to the silting basins in high embankments without much fear of breaches, or without any percolation which might be harmful to the contiguous lands if a proper system of drains is provided.

(7) The fact that the canals can be safely carried across the country in high embankments, so that the bed of the canal where it enters the silting basin can be fixed at or but little below the level to which it is desirable to raise the land, is an enormous advantage to the efficient working of such a silt-carrying channel and does away with the necessity of any final levelling off by manual labour which adds so much to the cost.

(8) The uniformity of the surface, when the colmata is finished, is remarkable and leaves little or nothing to be desired. Lastly, the works necessary for getting rid of the water after it has deposited its silt, are of the simplest character owing to the close proximity of the sea and small difference in level.

(9) The engineering works required, therefore, are not of a very costly character, but whether the larger works of colmata have been financially successful, it is impossible to say, as many of these works have been in operation for years, and no separate figures are available for the expenditure on colmata alone, apart from the expenditure incurred on embankments, drainage, agricultural roads—all of which are included under the head of Bonificazioni.

(10) Sir Edward Buck in his report 'quotes' figures which show how greatly the value of the land has been enhanced wherever colmata has been carried out.

The engineers, too, are of the opinion, and I see no reason to doubt it, that if such works could be commenced anew with the experience of the past, they would not only be very profitable but also be carried to completion in far less time. It must, however, be repeated that the Italian Government has embarked on these works for the sole object of getting rid of malaria, without regard to financial results.

(11) The amount of silt carried in suspension in the water of many of the torrents and rivers of Italy is enormous, as the following table shows :—

Name of torrent.				Proportion of silt to water by volume.	Percentage.
Esse	...	...	...	$\frac{1}{33}$	3
Foscana	...	...	...	$\frac{1}{20}$	5
Parce	...	...	...	$\frac{1}{33}$	3
Salcheto	...	...	...	$\frac{1}{20}$	5
Salarno	...	...	...	$\frac{1}{11}$	9

The above torrents are in Tuscany and the observations were carefully made by Signor Guili during flood time.

(12) The following table for the rivers visited during the course of this tour has been prepared from information supplied by the Engineers.

Name of river.	Proportion of silt to water by volume.	Percentage.
Volturno	$\frac{1}{100}$	1
Ombrone	$\frac{1}{10}$	10.00
Cornia	$\frac{1}{15}$	6.66
Lamone	$\frac{1}{10}$	10.00

The figures in the two tables above may be considered as maxima. They show the enormous amount of denudation which is going on in the Apennine ranges, largely due to the disafforestation of the hills, the increase of cultivation and the geological character of the soil.

(13) The following table has been prepared from the data given in Mr. Buckley's "Irrigation Works of India" for the purpose of comparison, and to afford some idea of the amount of silt in suspension in some of our Indian rivers.

Name of river.	Proportion of dry silt to water by weight.	Remarks.
Indus	$\frac{1}{237}$	Mean during the flood season observed during the latter half of July and first half of August.
Nile	$\frac{1}{670}$	During August when in flood.
Bengal rivers ...	$\frac{1}{1642}$	Mean of 234 experiments on rivers in Bengal at or near the surface.
Ganges	$\frac{1}{760}$	Average of 4 samples taken in August and September near the head of the Ganges Canal.
Do.	$\frac{1}{32}$	27th August during the Gohna flood at Narora.
Do.	$\frac{1}{103}$	28th August, day after Gohna flood at Narora.
Do.	$\frac{1}{3048}$	14th October at Narora.
Sutlej	$\frac{1}{47}$ to $\frac{1}{89}$	These are maximum figures for experiments extending over 4 years near the head of the Sirhind Canal and were taken in July and August.
Sone	$\frac{1}{180}$ to $\frac{1}{177}$	These are maximum figures for experiments extending over 4 years near the head of the Sone Canal in the months of July and August.

The above figures show how small a proportion of silt our Indian rivers contain in comparison with the Italian rivers and torrents. On the other hand the flood season is probably longer in India as in Italy there may be only 10 or 12 floods during the season lasting some 2 or 3 days: the rivers are mostly of a torrential character and rise and fall very rapidly.

(14) The following statement, also from Mr. Buckley's work, shows the two chief constituents (clay and sand) of the silt in the waters of the Sutlej and Sone. It will be noted that the proportion of clay is much greater in the Sone river.

Name of river.		Oz. of silt to 10 c ft. of water.	Volume of silt to volume of water.	Percentage by weight.	
				Clay.	Sand.
Sutlej river.	Average of 30 samples June 1895.	47.91	$\frac{1}{208}$	66.7	33.3
	Ditto 18 samples July 1895.	18.79	$\frac{1}{531}$	71.3	28.7
	Ditto 26 samples August 1895.	50.23	$\frac{1}{199}$	79.9	20.1
	Ditto 11 samples Sept. 1895.	4.88	$\frac{1}{2037}$	76.6	23.4
	Average for June, July and August.	38.97	$\frac{1}{256}$	72.6	27.4
Sone river.	Average of 12 samples June 1898.	15.4	$\frac{1}{648}$	99.6	0.4
	Ditto 23 samples July 1898.	32.0	$\frac{1}{312}$	90.6	9.4
	Ditto 26 samples August 1898.	23.6	$\frac{1}{423}$	83.4	16.6
	Ditto 22 samples Sept. 1898.	7.1	$\frac{1}{1406}$	95.4	4.6
	Average for June, July and August.	23.7	$\frac{1}{421}$	91.2	8.8

(15) In some experiments the writer made at Narora he found that the ordinary river sand of the Ganges, well pressed down and quite dry, weighed 90 lbs. per cubic foot, and that the ordinary fine clayey silt of the Ganges, well pressed down and quite dry, weighed 80 lbs. per c. ft. Ordinary silt may be taken as a mean of the two, or 85 lbs. when dry and well pressed down, so that to obtain the ratio of volume of silt to volume of water, when the ratios are given by weight, we must increase those ratios in the proportion of 85 to 62.4.

(16) Few irrigation Engineers will deny that *wherever fertilizing silt can be found it would be a grave error not to carry it on to the fields*, if it be economically possible to do so.

The agriculturist, too, in many parts of India, is alive to the advantages of silt.

In Midnapur, where the rainfall is sometimes as much as 10 inches in 24 hours, in order to take advantage of the fertilizing silt in the canal water the cultivators draw off the rain water as quickly as possible, in

order to admit the former. Long experience has proved to them that they get better crops by irrigating with the silt-laden water of the river than from the rain water.

(17) It is, however, remarkable, and the matter is under investigation, that the cultivators in the canal-irrigated districts of these Provinces make little or no use of the silt which they clear from their guls, although this silt is, to all outward appearance, identical with that to be found in our silt-traps which bear the most luxuriant crops.

(18) Lieutenant, now Sir Colin Scott-Moncrieff, in his *Irrigation in Southern Europe*, states, that the price paid for the waters of the Po in Italy was three times the amount paid for those of the Doria Baltia, owing to the fertilizing nature of the silt contained in the waters of the former.

(19) He also refers to the marked difference between the meadows irrigated with the silt-bearing water of the Durance Canals in France as compared with those of the clear cold Sorgues, so much so, that cultivators prefer to pay for the former ten or twelve times the price asked for the latter

(20) I do not, however, think that it has ever been sufficiently appreciated as to how much has been done in the past, and is now being done, in this respect, by our great Indian canals, which irrigate according to the last return some 20 millions of acres of land annually.

What, however, is the precise value to the land, we unfortunately have so far no sufficient data to show, but the cumulative benefits, continued as they are from year to year, must be very great.

The pores of the lighter and sandy classes of soil get filled and compacted by the infiltration of impalpable silt and are not only rendered more fertile, but require less water in the course of years.

(21) Dr. W. Leather has stated that the results of his experiments (though where these were made is not known) have led him to the conclusion that the amount of silt and its contents of nitrogen and phosphoric acid are but very small during the cold weather, and quite insufficient to replace the plant food taken from the soil by a crop of wheat; but, on the other hand, the silt-carried on to the land during the monsoon period contains very material quantities of these plant foods, which are probably fully sufficient to replenish the amount of plant food taken from the land by the rice crop.

According to the analyses he has made some 32 lbs. of nitrogen and 42 lbs. of phosphoric acid were supplied by canal silt during the monsoon, as against 8 and 10 lbs., respectively, during the cold weather.

(22) These figures point to the desirability of encouraging *kharif* irrigation by low rates, and seem to indicate that a season of drought, when irrigation is continuously in progress, may have some compensating advantages.

(23) I have made a rough calculation of the amount of silt deposited annually on the land in a year of average irrigation by the waters of the Ganges, Lower Ganges, Eastern Jumna and Agra Canals.

The amount would be sufficient to cover 14 square miles to the depth of 1 foot—no inconsiderable amount. This would be equal to an annual depth of deposit of $\frac{1}{200}$ of a foot.

(24) It has been estimated, from certain facts connected with the foundations of the two Colossi seated on the plains of Thebes, in Egypt, that the Nile, which has nearly every year flooded this plain for something like 2,400 years to a depth of 3 or 4 feet, has raised it by 6 feet: this is at the rate of $\frac{1}{400}$ of a foot per annum.

(25) Now, with regard to the question which Sir Edward Buck has raised on page 15 of his report—

First “as to whether the silt of Indian rivers and canals specially in sub-Himalayan tracts can be profitably utilized;” and secondly, “as

to how far existing canals can be utilized for the distribution of fertile silt." I can only speak of that part of India with which I am well acquainted, viz., the Jumna-Ganges Doab.

(26) As regards the canals in this tract, I have already shown that no inconsiderable volume of silt is annually deposited on irrigated lands, especially such as are irrigated during the flood season, although the film of deposit is almost infinitesimal.

The canals in this tract are generally working to nearly their full capacity when the earliest floods which are said to be the richest in fertilizing silt, occur, so that there is little or no scope at this season of the year for a further distribution of fertile silt.

To do so at a later period of the monsoon, when irrigation has slackened or entirely ceased, might lead to water-logging and its other attendant evils.

(27) With regard to the reclamation of inferior or worthless land through raising it with silt, as I have already stated, there are at the present time a few such schemes in operation and now that attention has been more particularly directed to the question it may be found possible to undertake more.

(28) The conditions are by no means favourable in this Doab for operating on Italian lines, as unless a tract of low-lying land happens to be in the vicinity of the canal (which is rare) a diversion canal would have to be constructed to carry the silt-laden water to the tract to be reclaimed, and generally somewhat expensive works to get rid of the clear water. In such cases, the water would be lost to the canal and silting operations would be intermittent and prolonged, depending on the requirements of irrigation.

(29) In some favourably situated places the work of reclamation from other rivers, not drawn upon by our canals, might be found profitable; but the preliminary investigation mentioned in Section 1, para. 20 would first have to be undertaken. Such works would, however, be local and limited in extent, for there is no doubt that our Indian rivers do not contain anything approaching the volume of silt to be found in the Italian rivers.

(30) Any large and extensive schemes for the utilization of silt for the reclamation and improvement of land in this part of India would not financially, in my opinion, pay, and could not therefore be undertaken.

(31) To carry out a scheme for the fertilisation of land on a large scale it would be necessary to construct canals similar to our irrigation canals, and a system of basins such as are to be found in Egypt.

The conditions in this part of India are not so favourable as in the Valley of the Nile, where the cost of basin irrigation, according to Mr. R. B. Buckley, has been between Rs. 45 to Rs. 60 per acre on an area of two million acres.

(32) Basin irrigation, too, means that only one crop per annum can be grown, and it is therefore not so profitable as perennial irrigation with which, in Egypt, two crops, at least, can be grown: hence, the tendency in Egypt at the present time is to construct more storage works to enable the basin irrigation to be converted into perennial irrigation.

(33) Colmatage has been carried out on a considerable extent in Southern France, but, even under the most favourable conditions, the cost is high.

(34) The following account is taken from "*Irrigation in South Europe*" as it has been referred to in Sir Edward Buck's Report:—

"M. Thomas having a property composed of gravel and stones and only fit for grass crops, laid some of it out in terraces, and obtained the use of 14 cusecs of water from the Crillon canal, which he turned

over it for the four winter months of every year. After three years, he found he had covered an area of 22·2 acres with a coat of the finest alluvial matter from 20 to 27 inches thick. The cost of the operation, including a water-rent of 16s., was just 7£ per acre. The land, which before had been worth £19-8-6 per acre, was valued after this improvement at £113-7-0, and yielded 7 or 8 crops of wheat without requiring any further manure."

The Crillon Canal takes out of the Durance River which carries a volume of silt approaching that which is to be found in the Italian rivers.

(35) It is quite possible that in some parts of India, particularly towards the sea coast, where the physical conditions may approximate more closely to those found in Italy and where there may be more fertilizing silt in the waters of the rivers, it may be found practicable to carry out large reclamation works, but such works in these Provinces are not in my opinion practicable on any extensive scale.

It would be quite out of the question here to carry the silting channels in high embankments as in Italy, on account of the inferiority of the soil and risk of interference with spring level. This restriction would add largely to the cost of silting operations, as it means that a good deal of the silt has to be lifted by manual labour.

(36) Thirdly, as to "whether notoriously unhealthy tracts such as the Tarai can be treated on Italian methods for checking malaria." I may claim to have an intimate knowledge of the Kumaun Tarai, having served in that tract for 5 years, and do not think that in this Tarai they can for the following reasons :—

The unhealthiness of the Tarai is due to the superabundance of water to be found everywhere, affording most favourable breeding grounds for the anopheles mosquito. The stoney talus at the foot of the hills, known as the Bhabar, absorbs the rainfall and a good deal of the water of its streams, and this water re-appears at a lower level in the form of springs.

It would not be possible to get rid of these springs even if a layer of silt could be placed over them.

(37) This Tarai is far less unhealthy than it was formerly, when it was the custom to dam the river and streams for the purposes of irrigation with large earthen bunds, which formed large and pestilential swamps behind them. A graphic description of the condition of the Tarai before these bunds were removed is given in a book on "Irrigation in the Tarai" by Captain W. Jones, R.E., the pioneer Irrigation Engineer in this part of the country.

The policy of removing all bunds and substituting masonry regulators has been steadily pursued since 1890, when an engineer of the Irrigation Department was first appointed to the Tarai and Bhabar Estates.

(38) The Tarai has a high slope and drainage works have in some places been carried out, but it is practically impossible to keep any drains which take out of these spring-fed swamps in an efficient condition, owing to the dense growth of vegetation which again springs up in their channels immediately it has been cut down.

(39) I have no doubt that the Tarai would be healthier without rice irrigation, but, on the other hand, it is only possible to induce cultivators to face the unhealthiness of the Tarai because some of the finest kinds of rice, which are extremely profitable, can be grown there.

(40) Since the discovery of the malarial parasite by Laveran in 1880 increased attention has been paid to the mitigation of malaria in Italy.

Recent researches there have proved that the larva of the anopheles mosquito live near the foci of the watercourses; that water

which is more adapted and more favourable to the life of the larva is clear, limpid stagnant water at an almost constant temperature issuing from the sub-soil or springs.

In such waters a great growth of water plants is to be found, especially of the filamentous kind. This is especially favourable to the life of the mosquito, as is also the shade of trees in the vicinity of these pools or springs.

(41) Now these are precisely the conditions to be found in the Tarai and Bhabar, and it is easy to understand why the country, in both the Tarai and Bhabar, becomes more and more unhealthy as one approaches the line of springs.

(42) In fact the Tharus and Bhoksas, who seem to become immune from fever provided they reach the age of puberty, are the only people who can live in their neighbourhood. The reason for this acquired immunity would be an interesting study for medical research.

(43) While on the subject of malaria I may mention that all houses in the malarious districts in Italy which are occupied by Government officials of any degree are provided with fine gauze netting protections to all doors and windows.

(44) I may also add, in this same connection, that the Italian Government is now taking measures to fill up or drain borrow-pits along the lines of railways, roads and canals, since they are found to afford favourable breeding-grounds for the mosquito.

(45) This is certainly a matter which might receive some attention in this country.

Railways are great offenders in this respect and roads in a less degree: canals are happily in a position, as a rule, to furnish earth for their banks from their excavation, without the necessity for outside borrow-pits, and these too are now avoided by the method described in paragraph 2.

(46) In the plains of India it is no doubt necessary that roads and railways should be kept above country level and the earth for their embankments therefore must be taken from borrow pits; but Government should fix some limit in the neighbourhood of cantonments, towns and villages within which no borrow-pits which are not provided with proper drains, should be allowed. I would suggest half a mile at least as the limit.

(47) Something too might be done to fill up or drain borrow pits which have already been dug in the vicinity of habitations, and this would afford really useful work for famine labour, so difficult to arrange for, besides being an object-lesson to the people in sanitation.

(48) I must here express my profound admiration for the great work that Italy is carrying out for the purpose of improving the sanitary and economic condition of its people, a work which is giving the best results in extirpating the malarial mosquito, and which should be an object-lesson to the whole world.

(49) The expenditure incurred since the Act of 1900 was passed as stated in paragraph 14, has been Rs. 2,62,32,312 or Rs. 43,72,052 per year—a very considerable amount for the poorest and most heavily taxed country in Europe, and an amount, too, which the overburdened tax-payer ungrudgingly bears.

(50) I believe I am correct in saying that the mortality from fever in India—most of which is malarial—is greater than that from all the other diseases together.

Even when not fatal in its effects, it saps the strength and energy of the people and is the cause of much human suffering. In a suggestive little book on malaria by W. H. Jones, M.A., recently published,

it is shown, and not without good reason, that malaria must be considered as one of the many factors—and a not unimportant one—in the downfall of the Greek and Roman Empires.

No measures within reason should be neglected therefore to mitigate this scourge of tropical countries.

(51) The description of colmata in the hills may seem unduly lengthy, but this system is new to India, and I have therefore considered it advisable to explain it in considerable detail in order that any one may understand it. Admirable as the system is, and perfect in its results, as seen at Mileto, I have some doubts as to whether it is generally adaptable to this country.

In the first place, it must be remembered that the land in Italy is under intense cultivation, and, in addition to the cereals and other crops grown, the vine and other fruit trees are cultivated on the same land, so that a return of lira 200 to 250 per hectare (Rs. 48 to 60 per acre) is not uncommon, whilst the best irrigated land in this country will perhaps give a return of Rs. 10 to 20 only on the average.

It is a system that on a large scale could only be satisfactorily carried out under an enlightened landlord, and would not be suitable where there are likely to be conflicting interests. It can be economically carried out where there is estate labour available—as at Mileto.

(52) In the appendix is given a statement showing the rainfall in various parts of Italy.

It will be noticed that the annual rainfall is about the same as in these Provinces, but is more evenly distributed throughout the year. The season of heaviest rainfall in Italy being late autumn and early spring, the precipitation in the rainy season is therefore much heavier in India than it is in Italy, and the soil is generally less argillaceous and consequently more friable.

It would not therefore be possible to deal with large drainage areas without expensive arrangements in the way of weirs and falls.

After the system has been completed, but little, except the most careful supervision to put in the very necessary “stitch in time” is required : and here again divided interests might prove an obstacle.

Still the system is worth a trial, especially in the neighbourhood of large towns where intensive cultivation with irrigation and manure can be practised : and there are many places down in the ravines bordering on the Jumna where the drainage areas are not too large, and where the soil is fairly strong clay, in which land could be built up with a series of silting basins such as have been described.

(53) I am firmly convinced that the problem to be solved in many parts of these Provinces and over a considerable part of India is not that of capturing the silt after it has found its way into our torrents or rivers but to prevent it getting there.

(54) There are some in Italy, too, who think that the problem there has been attacked at the wrong end, and that if measures had been taken to stop erosion in the hills the necessity for the large embankments, which have to be raised from time to time and which are to be seen across the valley of the Po and many other parts of Italy as a menace to the surrounding country, would not have been so great.

The formation of the unhealthy swamps and marshes along the sea coast is in a large measure due to the action of the sea on the waters of the rivers, so heavily charged with silt from the denudation of the hills.

I have no doubt they are right and that this would have been theoretically, the correct solution of the problem in Italy, but conditions had reached such a pitch that it was not economically possible.

Much can be done, however, to stop erosion and mitigate its evil results and this fact is now becoming appreciated in Italy, especially as such work as is to be seen at Mileto has been financially most successful.

(55) I have recently been inspecting some of the country which has been reported to be suffering from erosion in the neighbourhood of the Jumna, and I have formed the opinion that the most suitable method here for mitigating the effects of erosion and for conserving moisture in the soil is the method of field-to-field embankments and terracing. It is a fact, which unfortunately is only too patent in this season of drought, that the most fertile of soils cannot bear crops unless there is sufficient moisture in the soil or there are artificial means of supplying it.

(56) In a valuable paper on "Protective Works in India" by Mr. H. Marsh, C.I.E., in the *Agricultural Journal of India* for October 1906, a paper worthy of the close attention of all who are interested in the agricultural improvement of India, the following quotation from Mr. Impey's Settlement Report of the Jhansi District for 1893 on the immense value of field embankments is to be found: "Though not exactly a source of irrigation but rather a means of conserving the benefits derivable from rainfall, the system of field-to-field embankments, found especially in Moth and the north of Jhansi, may here be mentioned. *It can scarcely ever be said to have received the attention it deserves, for it is unquestionably of extreme value in protecting land against both erosion and kans, it recommends itself to the people themselves more than any other ambitious schemes as it has a direct fertilising effect.*"

* * * * *

"Field embanking is the simplest of all matters. A small earthen bund from 2 to 6 feet is thrown up along that side of a field which is crossed by the drainage from the field, flanks are added if necessary or, if the slope be very inconsiderable, the field may be inclosed by bunds on all four sides. One or two feet of water can in this way be kept up until after the end of the rains, and the land is thoroughly soaked before the winter sowings. In some parts of Moth and the north of Jhansi a series of these small bunds are found all down prolonged drainage slopes, and the land over which they have effect increases in darkness and in fertility every year.

* * * * *

"The advantages of the system are numerous. The people are willing to throw up the embankments and to take *takavi* for them. The rain-water is retained for the ground on which it falls instead of scouring into *nallas* : and as the *nallas* are deprived of their supplies they lose their velocity and power of cutting back into the good land above them.

The productive power of the land is increased and kans where it exists is drowned out."

This clearly explains the system and its advantages, and I endorse every word of it.

I would, however, add that where the soil is light and easily eroded as in the neighbourhood of the Jumna ravines in many districts, after the field bunds have been constructed up the drainage lines the fields should be brought to a level surface, so that the rainfall may be readily absorbed by the whole surface of the field and not concentrated towards the lowest part, where it often breaches the bunds owing to the pooriness of the soil or has to be let out by the cultivator by a cut to enable him to cultivate this portion of the field : which cut, from carelessness, is often not repaired before the next rainy season.

(57) In this particular part (pargana Shikohabad) and many other similar tracts the cultivators thoroughly understand the system and have adopted it to their advantage, but chiefly in those cases where

erosion is immediately imminent. The system has not been sufficiently extended, nor has it been carried far enough up the drainage lines, with the result that too much water comes down from above and their well-meant efforts are frequently wrecked.

The motto to be adopted in dealing with drainage causing erosion is "*Divide et impera*" and this is one of the main principles underlying the successful example of Colmata di Monte at Mileto.

(58) To quote again from Mr. Marsh's paper—"Where an embankment is made which affects the interest of several individuals, but is too small for State management, difficulties are sure to arise about its maintenance. One man wants to cut the bank of his submerged field so as to commence ploughing for the spring crop, whereas another wants to retain the water for his rice plants. Then, again, there is often trouble about injury to standing crops from the escaping water, whilst the necessary annual repair causes difficulty unless there is a strong headman to arrange these matters. Thus, although large embankments are of immense value, and particularly so where there is an enterprising village headman, yet *they do not have the same permanence as the small banks made by a cultivator round his own field*. The truth of this statement is rendered patent by the many neglected embankments found in Central India."

(59) I may add that large embankments for protective purposes are generally only suitable where the slope is gentle and a considerable area can be submerged, but where the slopes are rapid a system of field-to-field embankments is the only effective one; also that a few breaches in these field embankments do not materially injure its efficiency.

(60) Sir Edward Buck has submitted as one of the questions for consideration: "Whether schemes can be prepared for inclusion in famine relief programmes."

I can imagine no more useful famine works than a system of village relief works for the embanking and terracing of fields in tracts like those bordering on the Jumna, which are suffering from erosion.

It is these tracts where there is no canal irrigation and where, as a rule, the spring level, already very deep, is becoming deeper still, which have suffered whenever there has been insufficient rainfall and which are suffering at the present time.

Such work could be carried out by the headman of the village and should, of course, be subject to supervision by inspecting officers.

No technical skill but commonsense, and a good eye for the country, are necessary to supervise the work, as the people themselves will be frequently found thoroughly conversant with the system and its advantages. It will be popular as the people will be quick to recognize that it will be of permanent value to their fields and because the work will be carried out in close proximity to their homes.

(61) In treating of the serious evils of erosion Mr. Marsh writes:—

"The loss thus incurred in the cultivated area is more serious than any damage caused by *reh* efflorescence in the Doab, as the latter is temporary and remediable in the course of time, but the former is almost irrecoverable and permanent, after it has once reached a certain stage. Under the circumstances the matter deserves the most grave and serious consideration of Government with the object of introducing measures for the prevention of further loss, if not for the restoration of part of the land destroyed by the causes described."

With this I am in entire agreement. For the tracts bordering on the Jumna ravines field bunds and terracing are the first measure, I consider, that should be undertaken, as their effect in diminishing the

run-off from the surface of the land and in moderating, in consequence, the erosive power of the rainfall will be very considerable. Their effect will be further enhanced if the land is subjected to frequent ploughing during the period of the monsoon. The advantages of terracing the land in order to permit the soil to absorb the greater part of the rainfall falling on it, so that it may form, as it were, a reservoir of moisture against seasons of drought, and in order to prevent erosion and the carrying away of valuable earthy matter, are very widely recognised in Italy. And although the system of terracing has not been extensively adopted in that country on account of its expense, it is nevertheless recognized that for the treatment of cultivated land in the hills, it is the most perfect system that has yet been devised. However this may be in Italy, the system of field bunds and terracing in this country, with its heavier rainfall and more friable soil, cannot be considered to be complete solution of the difficult problem of the prevention of erosion, nor is it advocated as such.

The adoption of the system is strongly recommended, because in this country it is widely recognised as, at any rate, a partial solution of the problem, and because it is a system adapted to this country and is moreover economically possible. When the system has been thoroughly carried out in any tract of country, the flow in the ravines and *nallahs* will certainly be diminished and the erosive power of the run-off will, in consequence, be moderated. It may then be possible to restore part of the land already injured by erosion and build up land in some of the ravines by means of a series of silting basins, such as have been described.

Such works, however, should not, in my opinion, be carried out by State agency, but either as village relief works during famine or by State aid in the way of *takavi*, or grants-in-aid.

It is essential for the permanent success of such works that the people should learn to appreciate its advantages and not look to the State for its up-keep.

(62) In conclusion, Italy, like India, is almost entirely dependent on agriculture for its prosperity, and a great deal is done by the Government there to foster agriculture in every way.

One of the means adopted is the occasional appointment of a peripatetic Commission to examine and report on the improvements carried out by proprietors on their estates in different parts of the country, and then to adjudicate the rewards which take the form of titles or medals.

Encouragement of this kind would, I think, have good results in this country.

Rainfall in various parts of Italy.

Town.	Spring.	Summer.	Autumn.	Winter.	Annual.
	Inches.	Inches.	Inches.	Inches.	Inches.
Turin ...	10.94	9.18	8.44	4.81	33.37
Milan ...	9.94	9.31	12.62	7.62	39.49
Venice ...	7.44	8.03	9.56	4.94	29.97
Bologna ...	6.68	5.20	8.50	5.18	25.56
Genoa ...	11.40	6.62	20.37	6.46	44.85
Florence ...	8.96	5.20	12.50	8.50	35.16
Rome ...	7.25	3.20	11.37	8.80	30.62
Ancona ...	6.0	4.90	9.40	6.68	26.98
Foggia ..	4.6	2.70	5.40	4.55	17.25
Naples ...	7.2	3.10	11.67	10.45	32.42

Maximum rainfall 1.5 to 2 inches per diem.

APPENDIX I.

The statement appended gives particulars regarding 3 reclamation works now in operation by means of the silt of canals in the United Provinces.

No. 1 has been nearly completed, but Nos. 2 and 3 have been in operation barely two years.

The cost of maintenance has been estimated and is therefore only approximate.

The rental is estimated from the rental of other silt-traps on the Lower Ganges Canal. These traps are irrigated from the canal; water-rates being charged in addition to rent.

A portion of the Gorhni reclaimed area has been let at a rental of Rs. 12 per acre, and another portion at Rs. 6·5 per acre—the mean rental being Rs. 9 per acre.

Considering the favourable situation of the silt-traps on the outside of the canal banks, and that the only works necessary were a marginal embankment with outside drain and an inlet and outlet from and into the canal, the estimated return does not augur well for the financial success of works constructed solely for reclamation purposes.

APPENDIX I.

Particulars regarding some silt reclamation works on the Canals of the United Provinces

Serial No.	Name of silt-trap.	Canal.	Area inside marginal banks.	Total area.	Capital cost, including Canal Establishment and Tools and Plant.	Estimated cost of main-tenance, including land rent.	Total estimated cost, column 6 plus col-umn 7.	Estimated cost per acre of land, including value of land.	Original value of land per acre.	Estimated annual rent after improvement.	Percentage on capital cost.	Estimated number of years improvement works in operation.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Gorhni ...	Eastern Jumna...	157	191	Rs. 17,713	Rs. (1) 9,191	Rs. 26,874	Rs. 171	Rs. 73	Rs. 9	Rs. 53	Rs. 6	The land was originally <i>usar</i> and the whole volume of the Eastern Jumna Canal was diverted through the trap.
2	Piyaoli ...	Lower Ganges ...	195	236	Rs. 14,317	Rs. 15,683	Rs. 30,000	Rs. 153	Rs. 52.9	Rs. 9	Rs. 6.0	Rs. 4	The land was originally swampy and injured by percolation from the Lower Ganges Canal.
3	Harnaut ...	Ditto ...	400	463	Rs. (2) 35,792	Rs. 9,208	Rs. 45,000	Rs. 112	Rs. 50	Rs. 9	Rs. 8.0	Rs. 6	The land was originally swampy. It is intended to turn the whole volume of the canal through this trap.

(1) Includes 6 years' rental of 34 acres at Rs. 41 per annum.

(2) One hundred and ninety-two acres of land were given free by the zamindars on remission of land revenue (Rs. 163 per annum) on condition that the land should be restored to them after improvement; for purposes of comparison, the value of this land, at Rs. 50 per acre, has been added to the Capital cost.

APPENDIX II.

Since writing my report I have had an opportunity of inspecting the reclamation works carried out by Babu Lachman Pershad near the Agricultural Farm, Cawnpore, which has been referred to in Sir Edward Buck's report.

The reclamation consists in embanking and terracing the land along the sides of a ravine. This land had been somewhat cut up by the drainage down its slopes into the ravine. .

The system is precisely what I have recommended in paragraphs 55 to 62, section IV, of my report.

The land is fairly good light soil and is well manured : it has the additional advantage of canal irrigation and of being close to the large city of Cawnpore.

The work has proved remunerative, according to Babu Lachman Pershad, and brings him in a return of Rs. 10 per acre.

APPENDIX III.

Since writing my report I have been able to refer to the report of the Indian Irrigation Commission from which the following abstract has been made with reference to the value of field embankments, *vide* paragraphs 152 and 153, part I, and also in various paras. of part II.

The conclusions of this Commission will add much weight to what I have said in paragraphs 55—62, section IV of my report.

"152. *Field embankments*.—Excepting wells, there is perhaps no class of land improvement which is more extensively employed or more useful than those which we have included under the generic term 'field-embankment,' which comprises the following two classes of works:—

- (i) Embankments proper, known as bands or bandhis in the Central Provinces, bands in the Punjab and United Provinces, ahars in Bengal, bandhs in Gujrat, and *tals* in the Bombay Deccan. In broken country these works consist of dams across ravines or the beds of small streams and watercourses; and, in flatter country, of areas embanked on one, two, three, or even four sides, the banks being of widely varying height and dimensions, from the low bank which encloses a rice field to the high and long embankments which enclose many acres of wheat in the Central Provinces. In these latter Provinces and in Bundelkhand (United Provinces) field embankments are found to be of special value in eradicating the noxious weed-grass known as kans, which succumbs to the complete and continuous flooding given by water held up within the embankments.
- (ii) The terracing and levelling of sloping lands, with the object of preventing erosion of the soil and conserving moisture in it.

153. Generally no hard-and-fast line can be drawn between the two classes of works, as the damming of a dry watercourse or drainage depression results in the accumulation of silt and soil till the terrace is formed; and a succession of terraces is often formed by a series of bands. By means of these works many acres of land have been rendered fit for cultivation, and capable of withstanding the effects of drought, in most unpromising tracts of country, such as the barren uplands of the Bombay Deccan and Central India. In more fertile tracts, also, they render possible the cultivation in the rabi season, after the close of the monsoon, of the more valuable wheat crop in place of the less valuable millets and other monsoon crops. In South Bihar (Gaya, Patna, Shahabad), Chota Nagpur and elsewhere in Bengal, and in the Mirzapur District of the United Provinces, they secure the rice crop against the vicissitudes of ill-distributed rainfall. In hilly situations cultivation is generally impossible without terracing on an extensive scale, and "bundling" occurs extensively in most submontane tracts. Ravine lands occur mostly near the banks of the large rivers traversing the great alluvial Gangetic plains. An excellent example of reclamation of such land is to be found on the Government Dairy Farm at Allahabad. But with regard to the immediate purposes of our inquiry, the main value of the embankment consists in the prevention of the escape of rain-water until the soil has been thoroughly saturated, in the permanent storage of moisture, and in the consequent raising of the sub-soil water level to the benefit of well-irrigation in the vicinity. In some cases, as in the Central Provinces, the size of these embankments might be sufficient to justify their occasional construction by Government in ordinary years. But in the great majority of instances the work had best be left to private enterprise, for which it is peculiarly well suited. A good deal of money has been advanced for this purpose in the Bombay Presidency both in ordinary years and in years of famine. Substantial sums were given also during the famines in the Central Provinces. These embankments have also been made with considerable success as relief works in the State of Gwalior, where we saw several satisfactory instances of land reclaimed or in the process of being reclaimed by their means. Relief was also employed on them in Bundelkhand, in the Central Provinces and in the Bundelkhand States. They are likely to be useful in many tracts of black soil where direct irrigation would not be suitable. In the various Provincial Chapters we have recommended that strong encouragement should be given in ordinary years to the construction of these works, by liberal *takavi* advances, and by free grants in tracts exposed to famine; and that in districts where their construction is likely to be of use, famine labour should be extensively employed on them."

APPENDIX IV.

FORESTS AND RUN-OFF. (ENGINEERING RECORD, SEPTEMBER 7TH, 1907.)

It is matter of dispute whether the removal of forests always effects the amount of run-off from water-sheds, for records of certain European districts indicate that deforestation has not been followed by increased floods and erosion of the soil. In examining the subject in detail, however, it has been observed repeatedly that where the removal of the forests has been followed by agricultural work which opens up the pores of the soil, assuming the latter to be somewhat coarse-grained, erosion may not be materially affected. This relation of forests and agriculture to run-off and soil erosion is pointed out in an exhaustive bulletin on the Potomac River basin recently issued by the U. S. Geological Survey, from which the following notes are taken.

If the rainfall is all absorbed, as by a coarse, sandy soil, there is no run-off and no erosion. As the soil becomes finer in texture, more compact and correspondingly less pervious, the rain is not absorbed as fast as it falls. The impact of the rain drops loosens the fine particles of soil, and unless absorption takes place the drops gather into small streams and rivulets, transporting with them, by a system of natural elutriation, the finest particles of soil and leaving behind the larger and heavier grains. At first this is entirely due to the hydraulic action of the impinging rain drops, but no sooner do the rivulets gather power, either by the added volume of the water or by increased gradient, than they likewise begin cutting loose and transporting the soil.

The capacity of a stiff soil for water is, in practice, 35 to 50 per cent. of its volume, or for ordinary formed soils 4 to 5 inches of rainfall to the surface foot. In spite of this capacity, the greater part of a heavy shower will usually not be absorbed. The coarse structure of a sandy soil permits the rainfall to be absorbed as rapidly as it falls. In a clay soil, unless in a high state of tilth, the pores are similar and there is less open cellular communication between them, and absorption must largely take place through cracks, worm holes, and root holes, and, when there are few of these, absorption is largely retarded until the air can be expelled. In the extreme case, that of a raw clay soil with its surface puddled by a previous heavy rain, the result is, as King points out, "that when a heavy rain falls, the close structure and feeble granulation result in the surface pores of the soil becoming so quickly closed that the soil air has little opportunity to escape, and yet only so fast as it does escape, can rain enter the soil, and hence during heavy rains the water accumulates quickly and extensively upon the surface."

The greater portion of the tilled soils of the Potomac basin, especially of the lower part, are of heavy type and close texture, and the run-off from them indicates failure to absorb. But were they well granulated and in good tilth they, as well as the more permeable sandy soils, could readily absorb, without undue accumulation of surface water, a much heavier rain than commonly falls at one time on the Potomac basin.

The porous condition or granulation of a heavy soil necessary to effect absorption is best procured by the addition of humus.

There is room for a large storage of storm water in farming soils, and more rational farming methods must ultimately lead to this. The effect of such storage would be reflected in a diminished run-off of flood water, especially of midsummer rains. Little of the water thus accumulated would normally pass off as seepage to spring and river flow. The improved growth of the crops would utilize such stored water and give a more constant and available amount of soil moisture.

Any additional storage, either transient, tending to prolong or distribute a flood crest, or deep seated, tending to increase the amount of the dry-season flow, can be secured only in the forest soil, except in sandy phases, takes place very largely through the medium of humus. The amount of water which is actually retained by a thin humus is small; in fact, a thin humus is usually far more litter than humus and has a very low retentive capacity; but the chief function of humus, except where it has accumulated to a great depth are (1) to maintain the volume and depth of the soil by preventing erosion, (2) to secure the porosity of the soil, (3) to promote the absorption of rainfall by the soil in retarding the run-off of heavy showers until the water can be absorbed, as the air is gradually expelled from the soil, (4) to act as a mulch and lessen the evaporation of soil moisture.

On coarse, deep sands of low gradient the office of humus is at a minimum. There is no surface flow of storm water and no soil transpiration; evaporation of soil moisture is low both from the surface of the soil and from transpiration by the xerophytic flora, and the larger part of the rainfall passes as percolation. With

an increase in the clay component greater radiant, and a decrease in soil depth, humus becomes more essential in supplementing the water-absorbing and water-carrying capacity of the soil, its function in this respect attaining a maximum on heavy, shallow clays of mountain slopes.

Where the humus is thick, however, it possesses a high storage capacity. While there is some doubt in regard to the exact amount of water humus is capable of holding, the quantity is relatively large. The lowest estimates by Ebermayer place it at considerably more than its own weight, and Wiley's investigations of Florida mucks give it about the same capacity; while Wollney places it at about 4 times its weight, and Henry's laboratory experiments tend to confirm Wollney's high limit. The capacity of humus must vary, however, not only with the state of decomposition, but with its origin as well, since the pore space is the final determinant of its water-bearing capacity. The undecomposed litter, which covers the humus and from which humus is formed, does not exhibit the characters of humus toward water. It protects the humus, as humus does the underlying soil, from excessive transpiration by surface water and in addition from excessive evaporation, acting as a mulch.

The accumulation of humus on forest soil depends, if it has neither been disturbed nor destroyed, on the kind of species forming the forest and to some extent on the soil, the destruction of humus proceeding rapidly on loose, porous soils, which permit freer circulation of air and afford the condition best suited for bacteriological activity, and since many species of trees, especially the white oak and chestnut, have a wide range of soil adaptability, their capacity to accumulate humus is modified both by their rate of growth on the soil and by the oxidizing capacity of the soil on which they happen to be growing.

APPENDIX No. V.

The following mechanical analysis of silt taken from the bed of the Ranjitpur Distributary, Cawnpore Division, Lower Ganges Canal, has been kindly furnished me by Mr. W. H. Moreland, C.I.E., Director of Agriculture.

	In 100 parts. .					
Moisture and organic matter	...	...	...	...	...	3.74
Chalk	...	...	...	...	...	1.98
Sand, coarse and fine	...	...	...	...	...	83.71
Silt	...	...	...	...	...	6.66
Fine silt	...	...	...	...	...	1.20
Clay	...	...	...	...	...	2.27

No alkaline soluble salts were found. Silt and fine silt are used to denote the particles too fine to be classed as sand and too coarse to be taken as clay.

The Agricultural Chemist states that "The amount of 'clay' and 'fine silt' is very low. Soils containing less than 20 per cent. of fine silt and clay are generally found deficient in water-retaining capacity, and a large application of this on land already deficient in this respect would, I imagine, be risky."

The result of the inquiries I have had made among the cultivators confirm this.

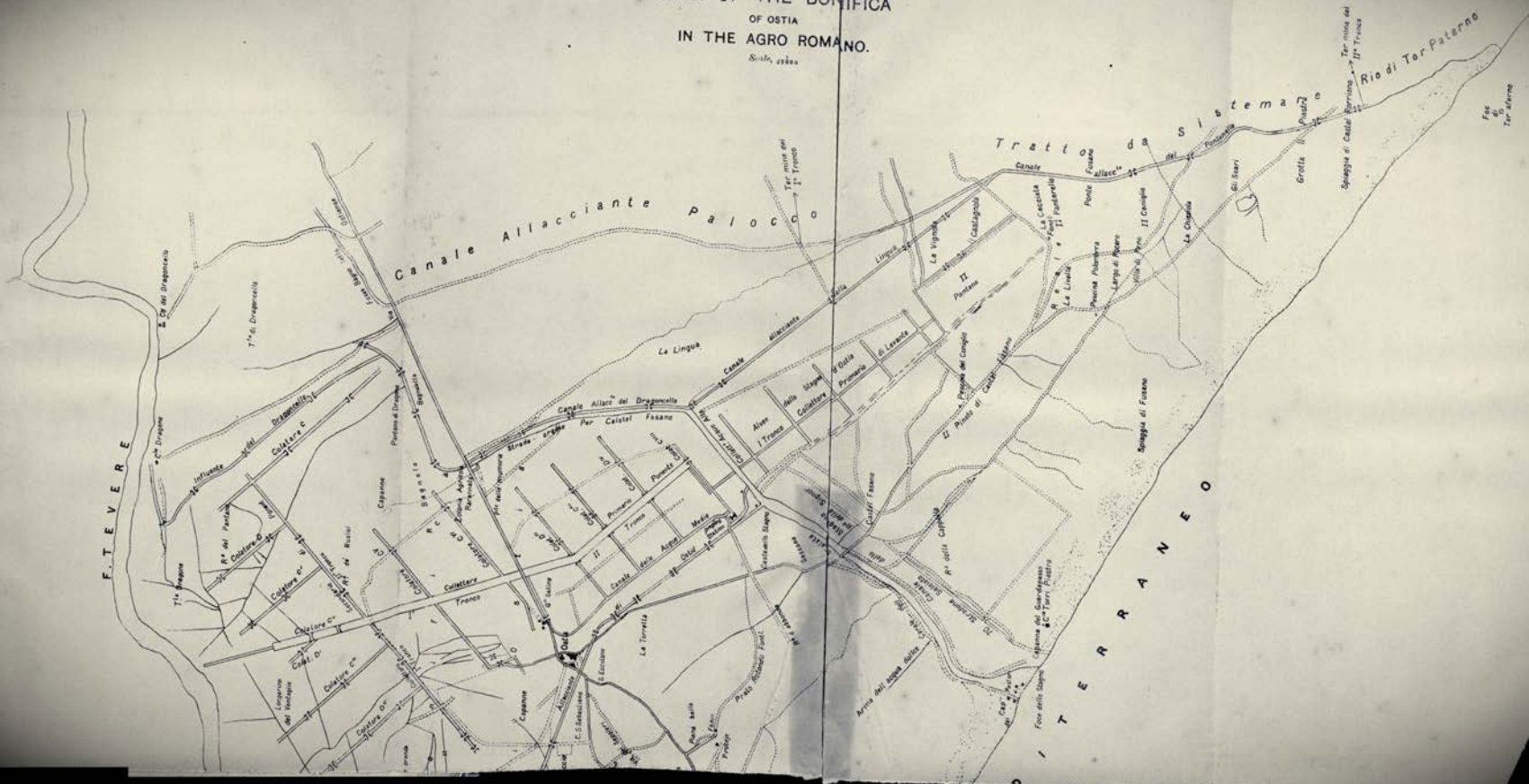
The silt analysed would be identical with that cleared from the cultivators' gul, and is precisely similar to that caught in the silt traps.

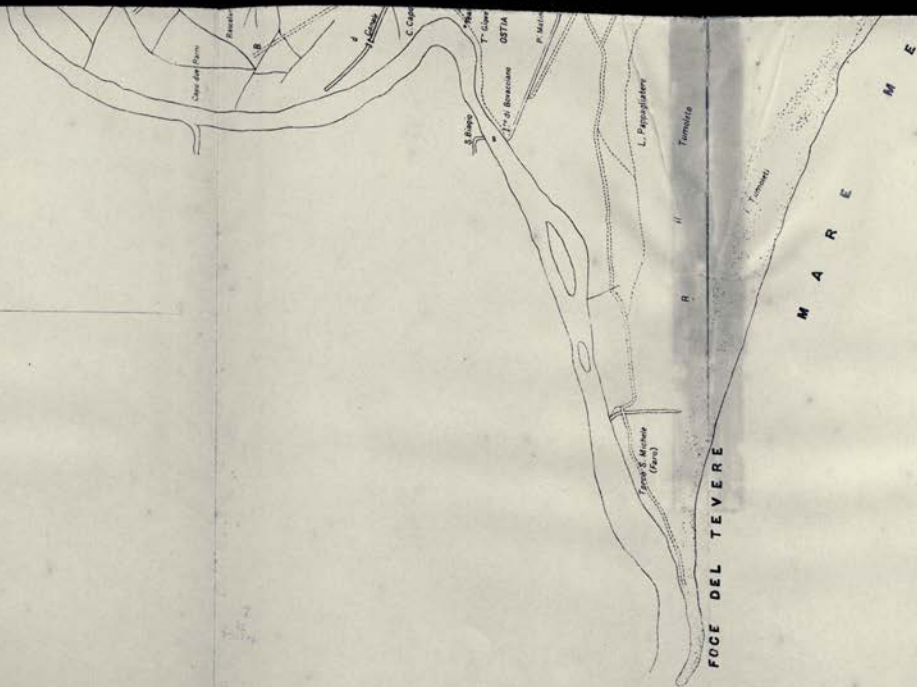
The cultivators make little or no use of it: they consider it somewhat beneficial to clay lands for rabi crops, but harmful for heavy rice lands and lands with light soil, as it renders them more thirsty.

The amount of clay and fine silt is remarkably low, and compares very unfavourably with the silt in the Italian Rivers, the Lamone for instance.

The above facts appear to prove that the silt brought down the Lower Ganges Canal system and desposited in the irrigation channel and guls has little or no value as a fertilizer for the improvement of the light sandy lands which mostly predominate in this Doab.

PLAN OF THE BONIFICA
OF OSTIA
IN THE AGRO ROMANO.
Scale, 1:10000





NOTE.

Canale allacciante,	... Intercepting drain.
Canale collettore,	... Collecting drain.
Colatore,	... Percolation drain.

GENERAL PLAN
OF
BONIFICA OF MANFREDONIA.



REFERENCES.

	Area.
A. First silt basin of the Cervaro in operation	1,310 acres.
B. Second " " under construction	1,225 "
C. First " of the Candelaro in operation	1,297 "
D. Third " of the Cervaro projected	1,125 "
E. Sipontine Marsh drained by pumping	900 "
Marginal bunds of basin	
Overflow Weir	
Outlet	
River embankments	

CERVALLO TORRENT RECLAMATION WORKS.

SILT BASIN No. 1.

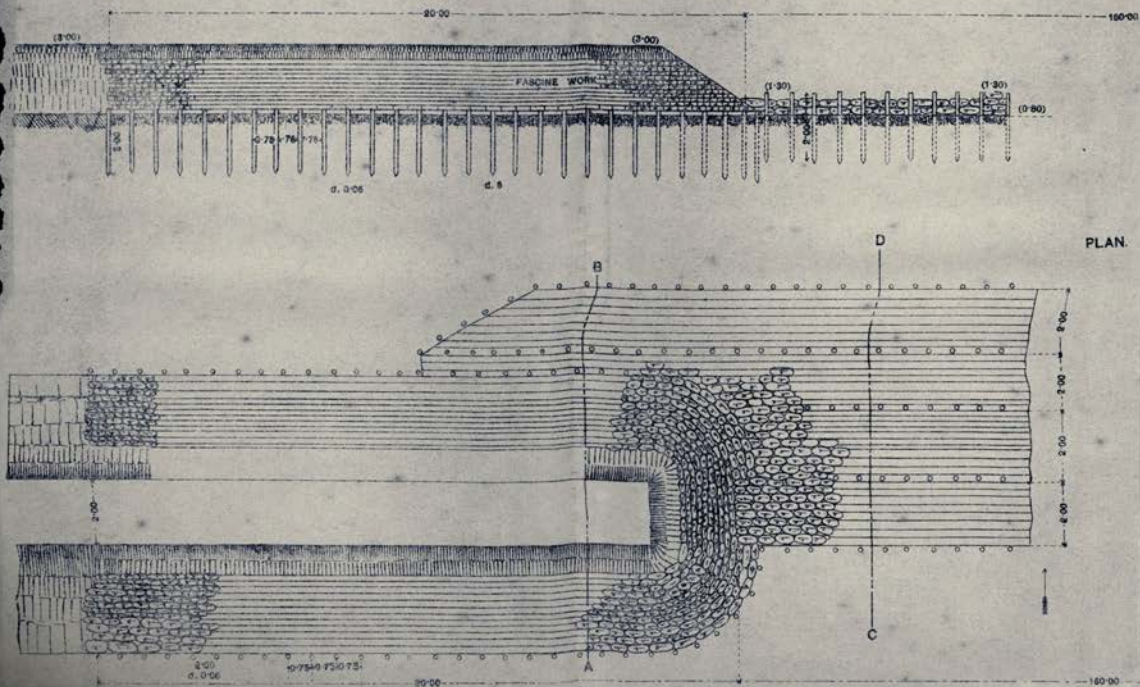
PLAN OF OVERFLOW WEIR.

Scale, 1:10

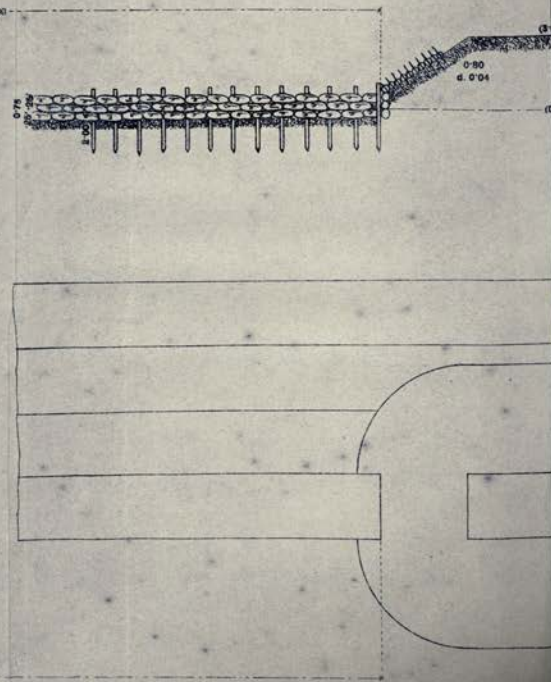
Note.—Dimensions in metres.

HALF ELEVATION.

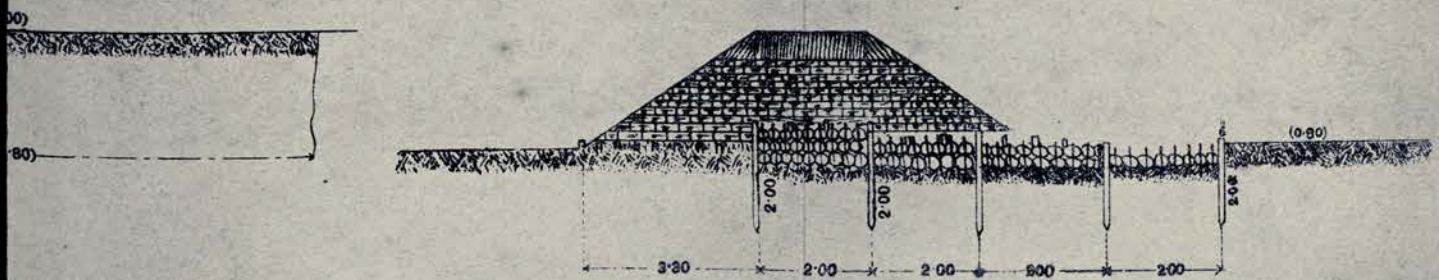
HALF LONGITUDINAL SECTION.



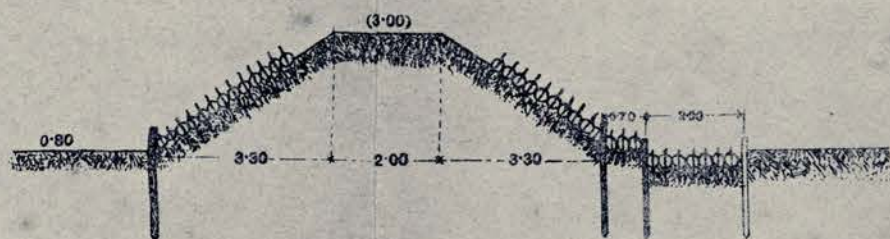
PLAN.



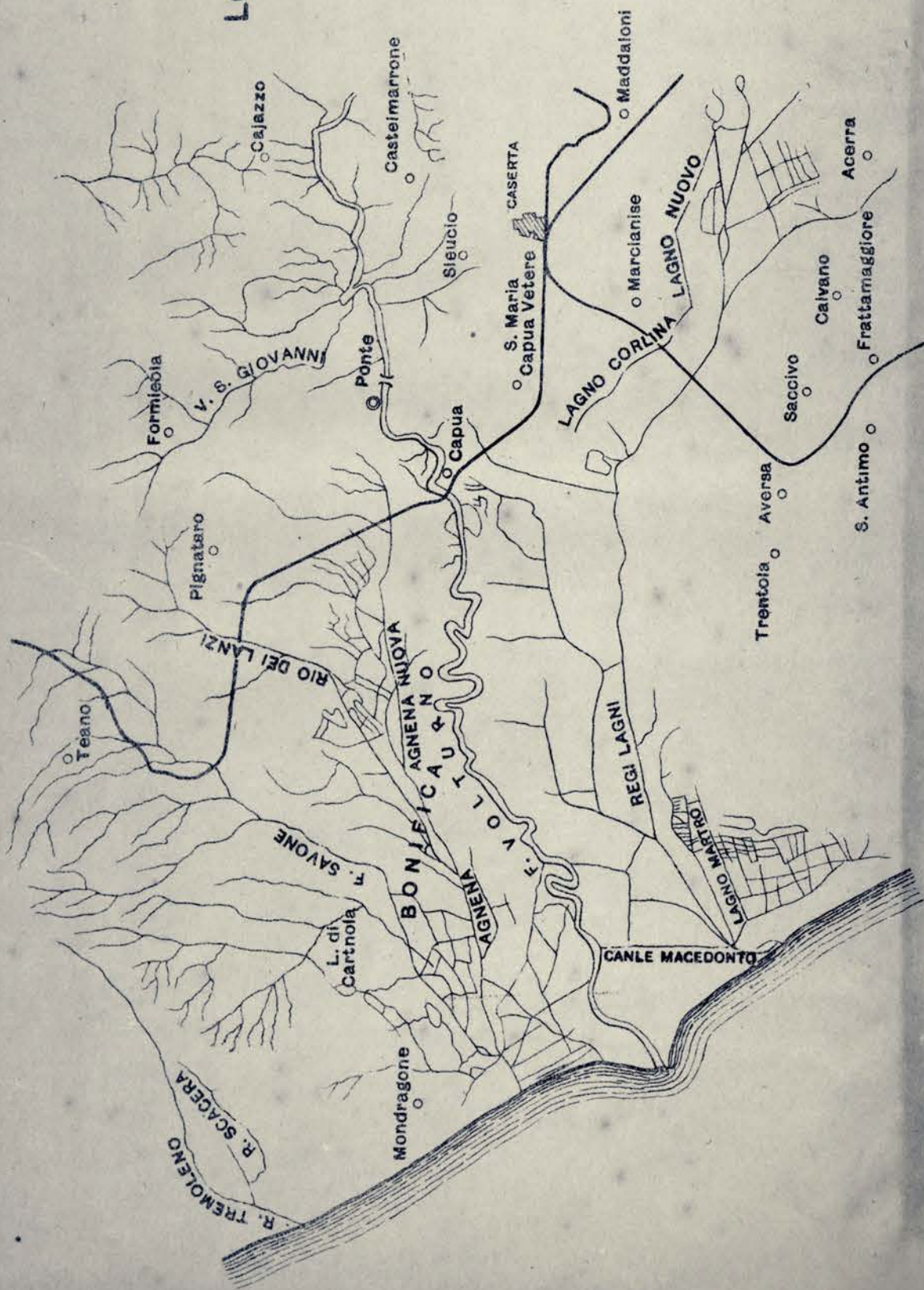
SECTION C D.



SECTION A B.



GENERAL PLAN
OF
BONIFICA
OF
LOWER BASIN OF VOLTURNO.
Scale 1:100,000.



PLAN OF THE LOWER BASIN OF THE
VOLTURNO RIVER,
COMPRISED WITHIN THE RADIUS OF THE BONIFICA.

Scale: 1:50,000

- I. Area of the drainage basin within boundary line. Area, 207,000 sq. km.
 - II. Area irrigated by drainage. Area, 21,000 sq. km.
 - III. Area raised by the right waters of the River Volturno and the various canals: River del Lago, River del Fiumicino, and River S. Paolo. Area, 15,000 sq. km.
 - IV. Area now under cultivation. Area, 13,500 sq. km.
- Work commenced in 1875.
Expenditure from 1875 to 1906. It is 1,500,000.



- REFERENCES
- Land already raised with silt. [Shaded box]
 - Land raised by the right waters of the River Volturno. [Shaded box]
 - Land raised by the right waters of the River Volturno. [Shaded box]
 - Boundary of the Bonifica. [Dashed line]

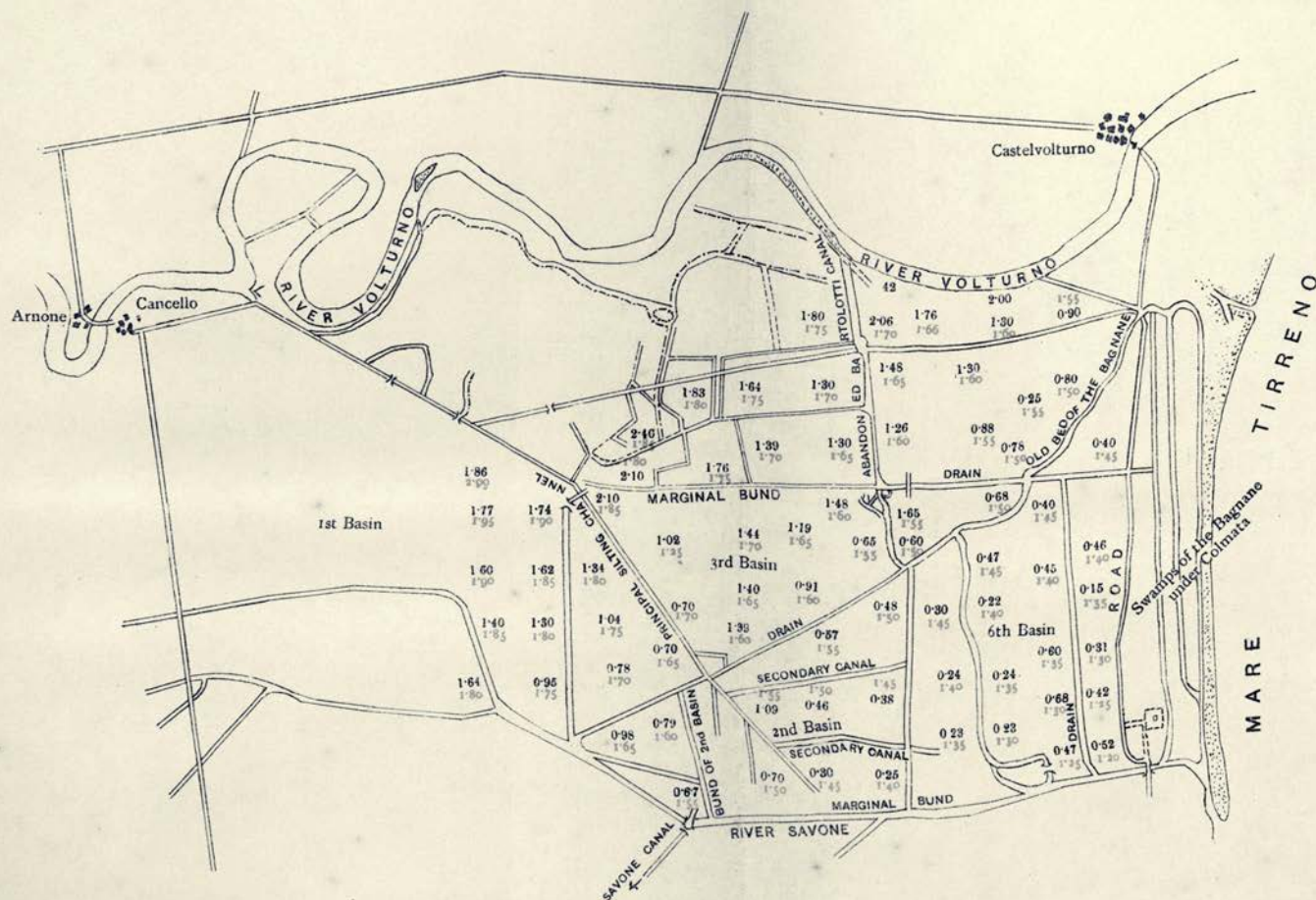
PLAN OF LOW-LYING COUNTRY

ON THE

RIGHT OF THE VOLTURNO RIVER

showing the Diversion Canal and Silting Basins.

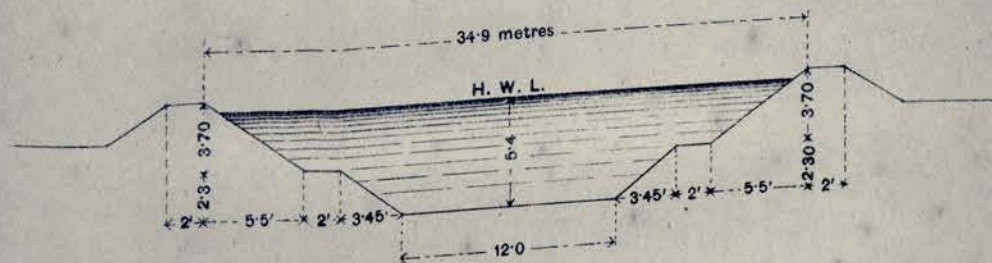
Scale, 1:25,000.

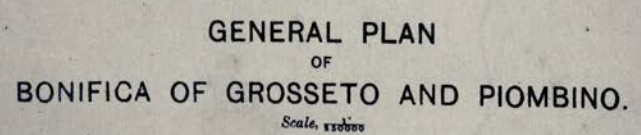


N.B.—The figures in black show the original height above sea level, the figures in red the height to which the land is to be raised above sea level.

CROSS SECTION OF NEW DIVERSION CANAL FROM THE VOLTURNO.

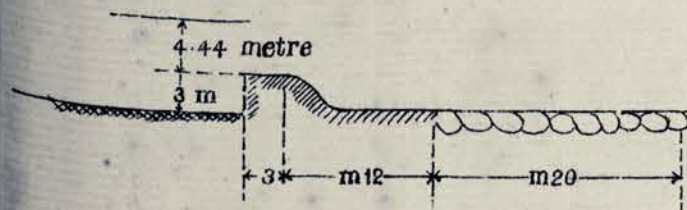
Max. discharge 7,100 cusecs. Slope 0.40 per 100





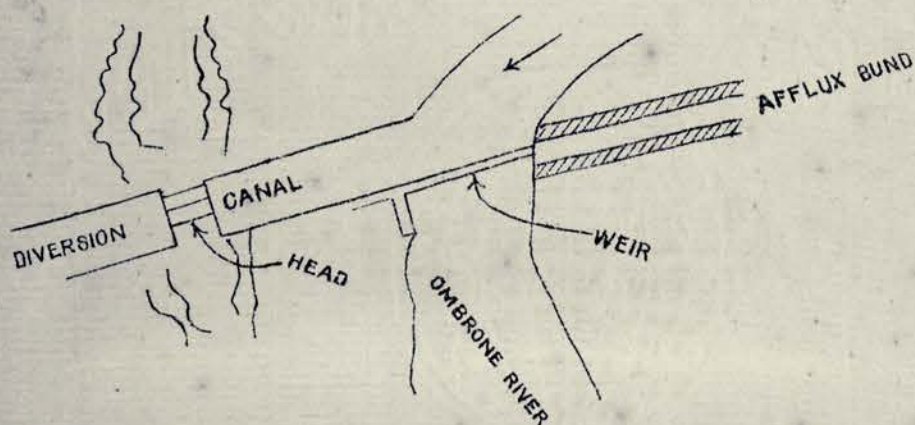
COLMATA OF CASTIGLIONE SWAMP

GROSSETO



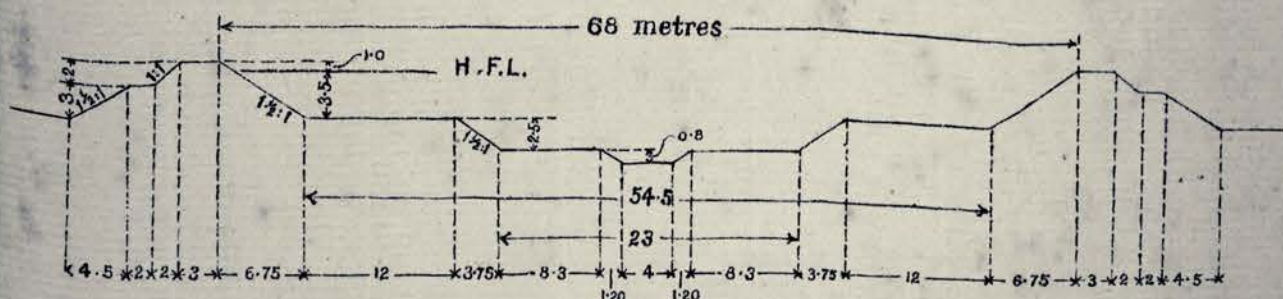
SECTION OF DIVERSION WEIR OF THE OMBRONE. LENGTH 150 ME:

FIG. 1



PLAN AT OFF-TAKE OF THE DIVERSION CANAL

FIG. 2



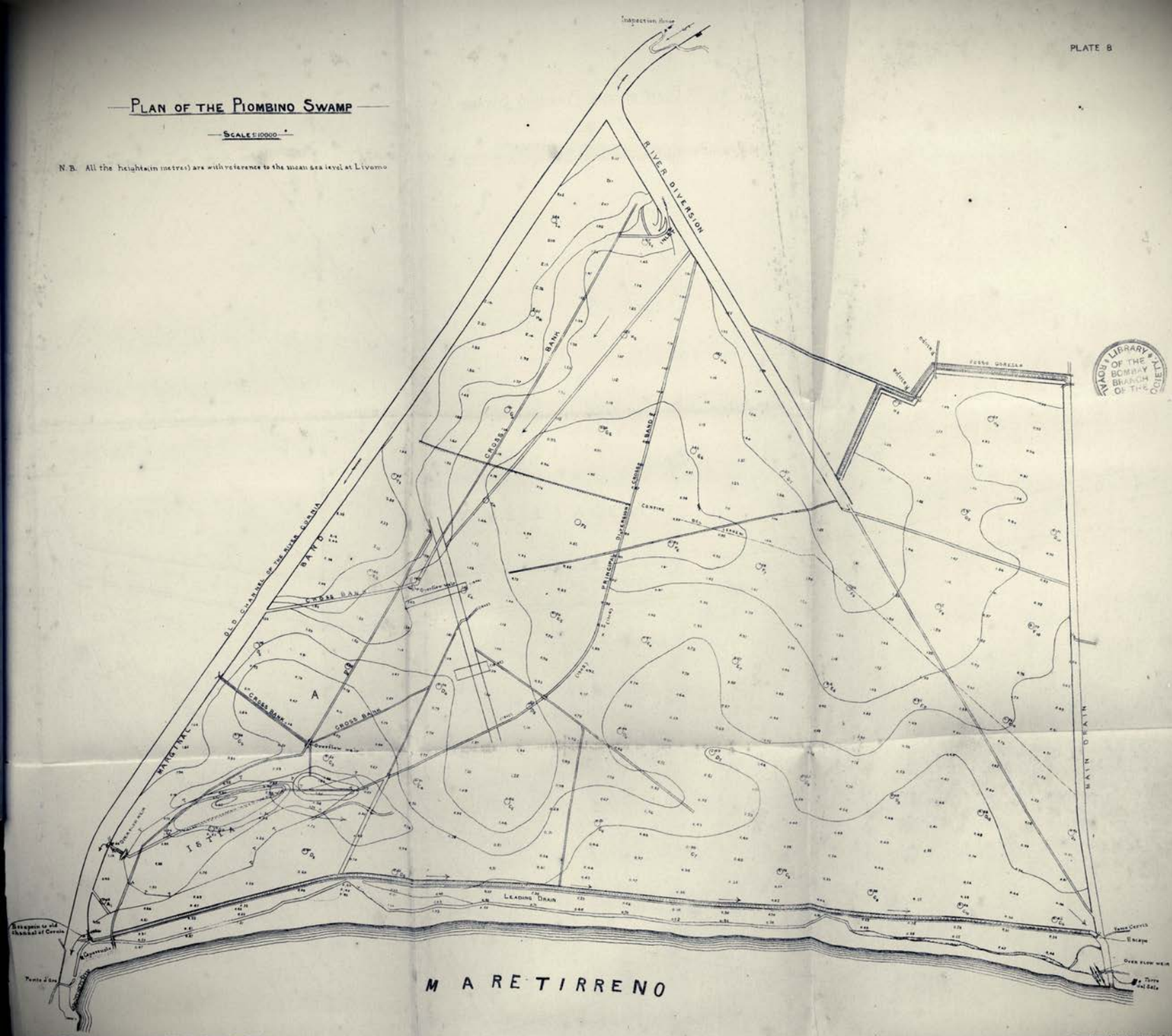
CROSS SECTION OF 2ND ENLARGEMENT
OF
THE DIVERSION CANAL FROM THE OMBRONE

FIG. 3

PLAN OF THE PIOMBINO SWAMP

SCALE 1:10000

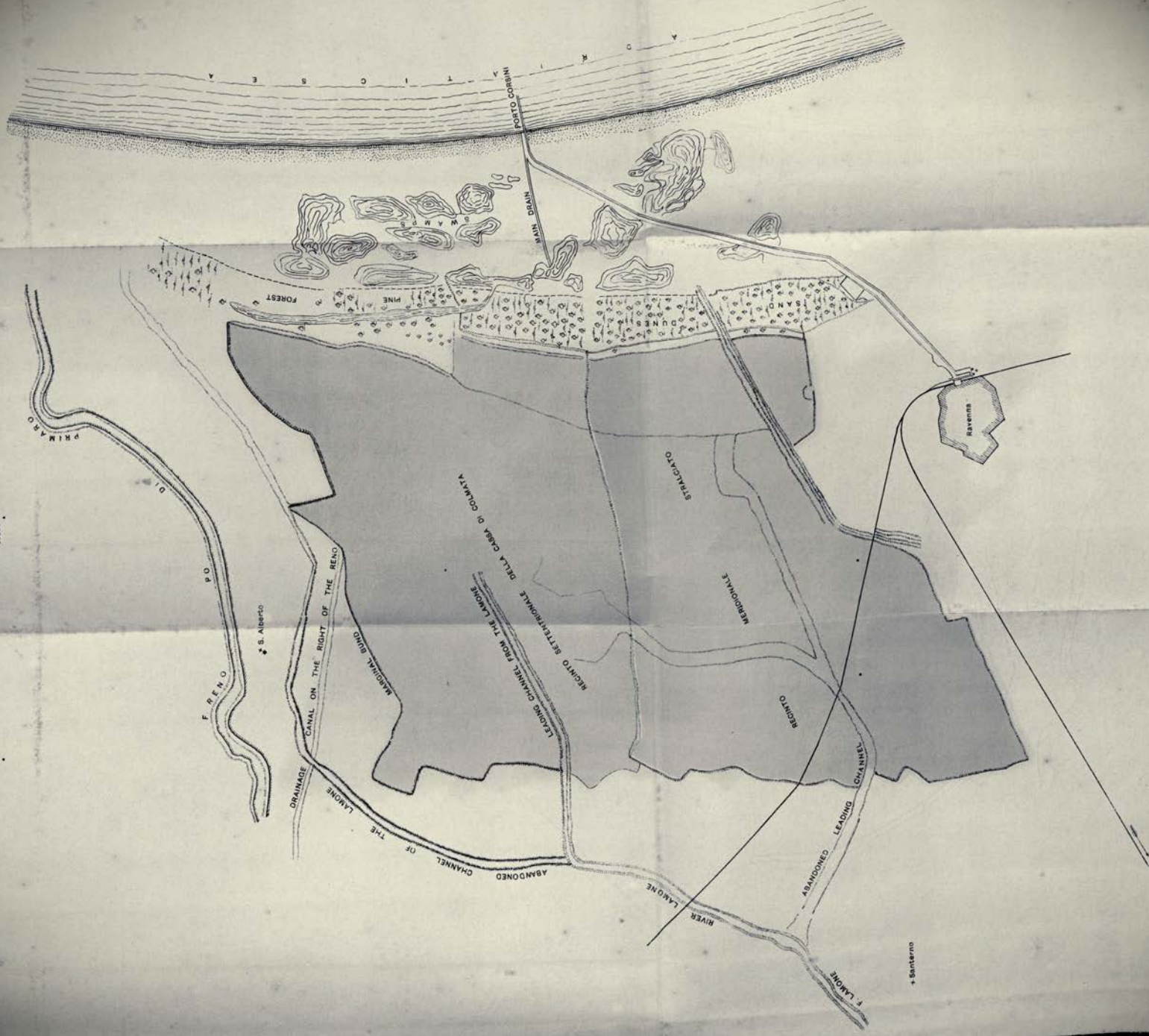
N.B. All the heights (in metres) are with reference to the mean sea level at Livorno



MARE TIRRENO

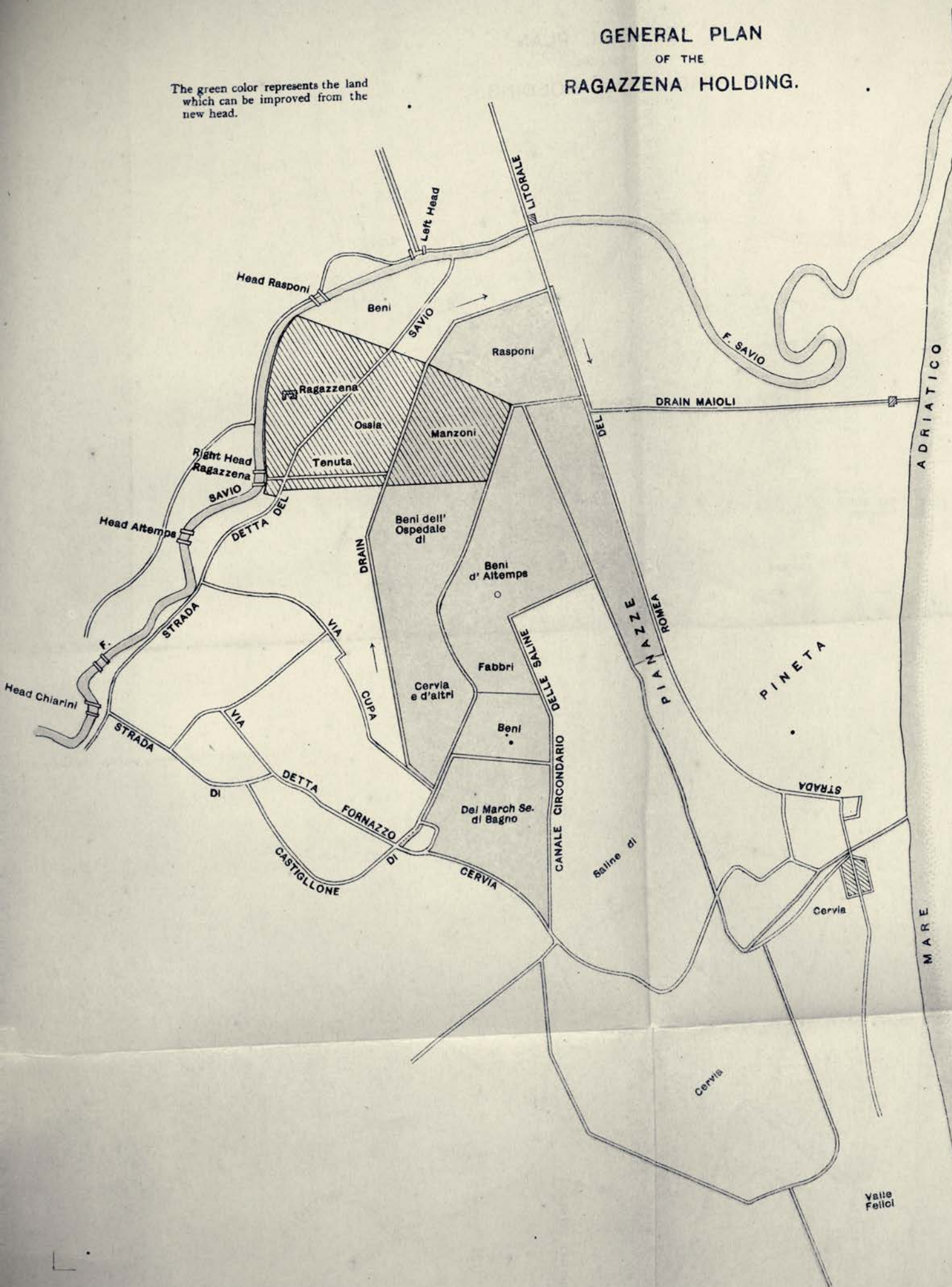
BONIFICA AT RAVENNA SILT BASINS OF THE LAMONE.

Scale 1:50,000



GENERAL PLAN OF THE RAGAZZENA HOLDING.

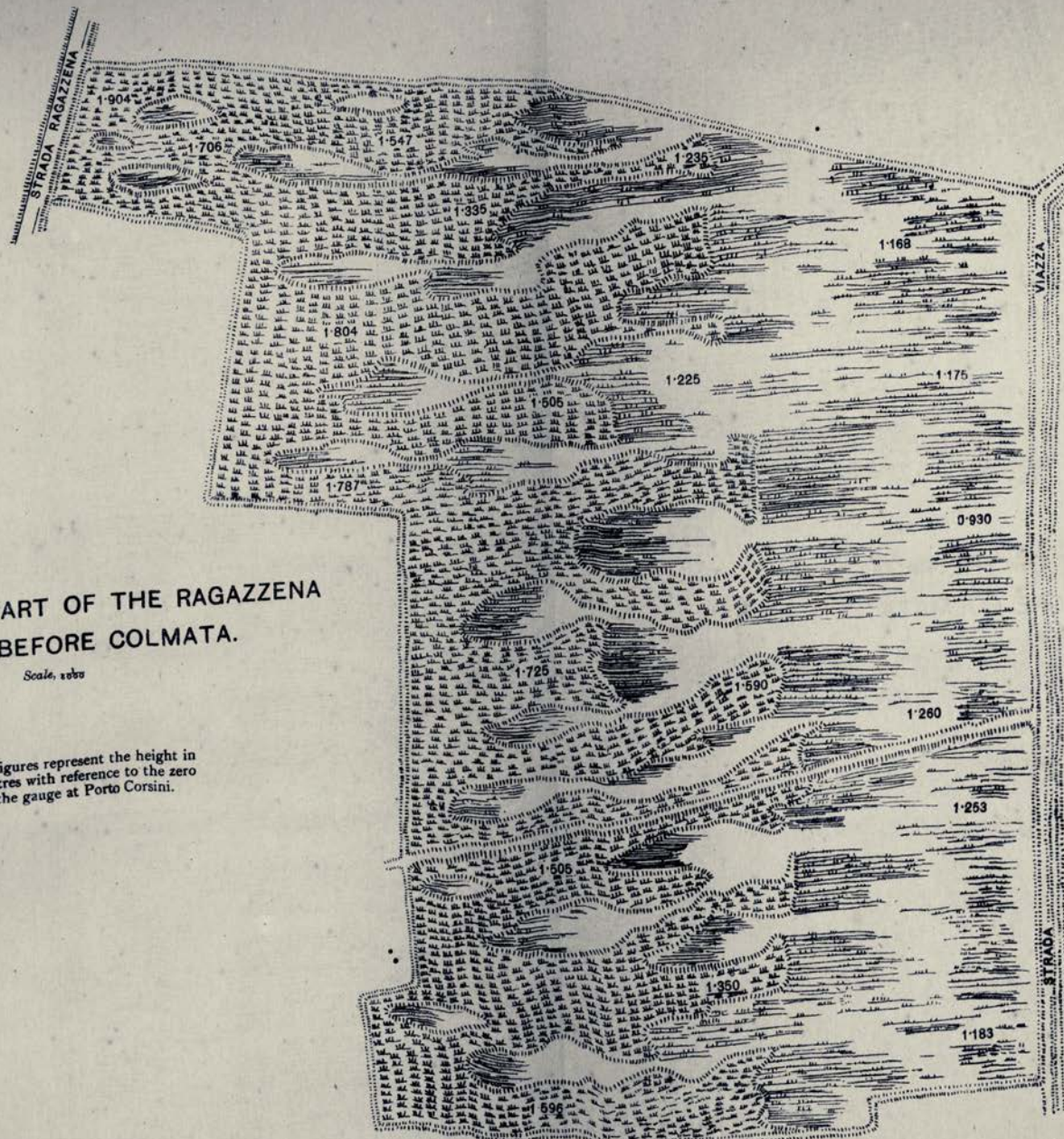
The green color represents the land which can be improved from the new head.



CONDITION OF PART OF THE RAGAZZENA HOLDING BEFORE COLMATA.

Scale, 1:200

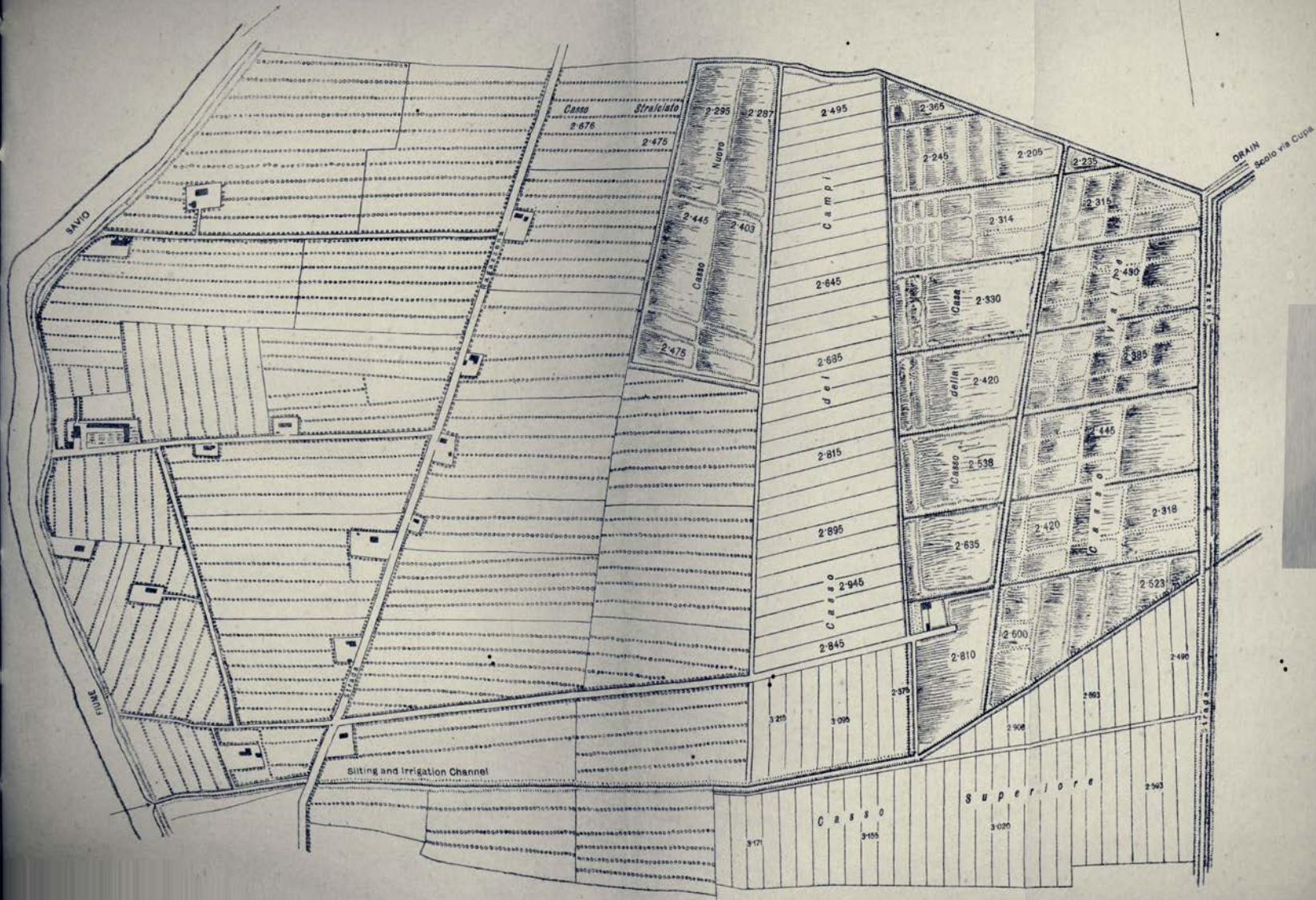
NOTE.—The figures represent the height in
metres with reference to the zero
of the gauge at Porto Corsini.



PRESENT STATE OF THE RAGAZZENA HOLDING.

Scale 1/1000

PLATE 12



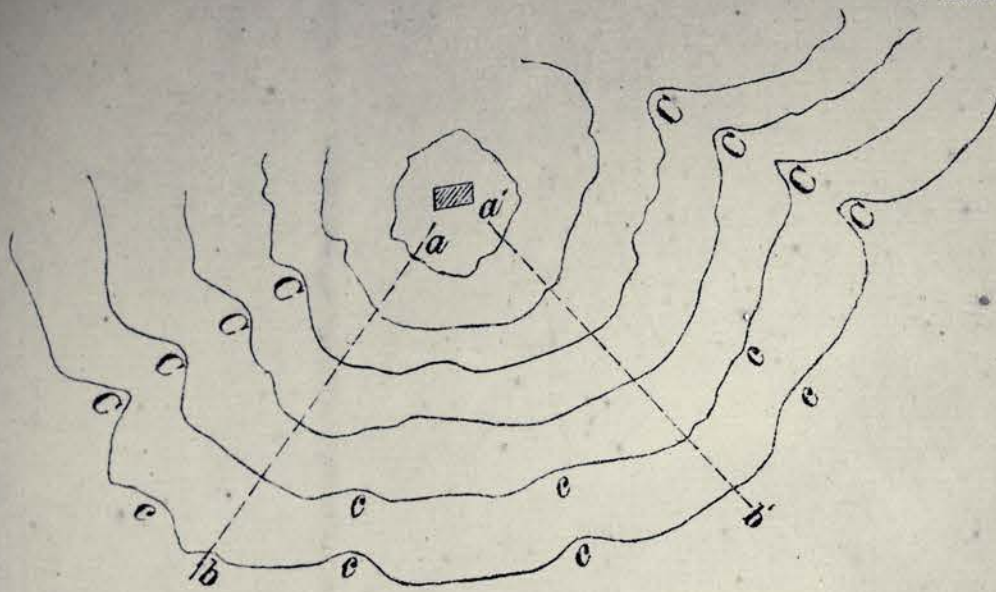


FIG. 1

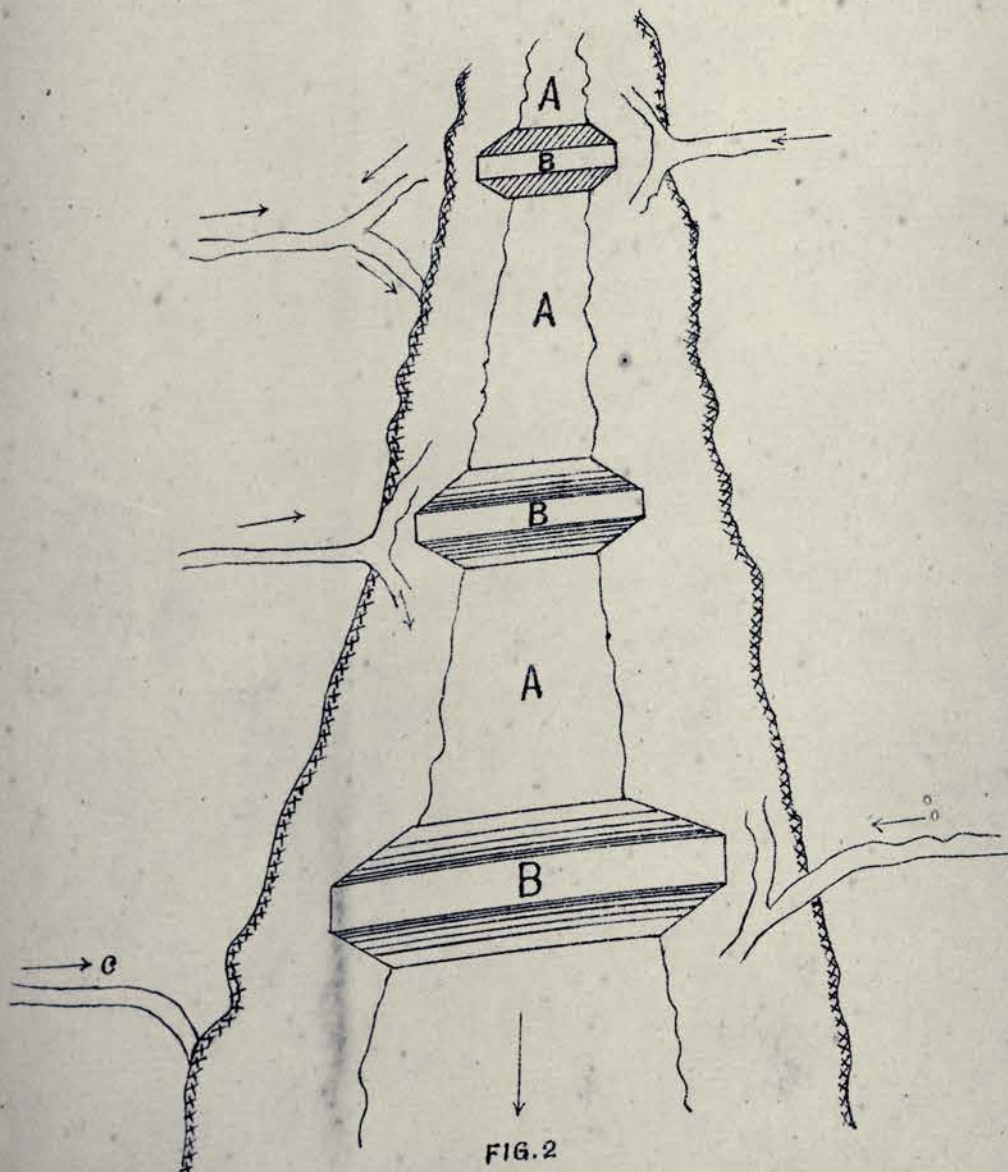


FIG. 2

DIAGRAMMATIC SKETCH OF SYSTEM OF SILT BASINS

A. SILT BASIN

B. BUNDS

C. SILT CARRYING CHANNELS

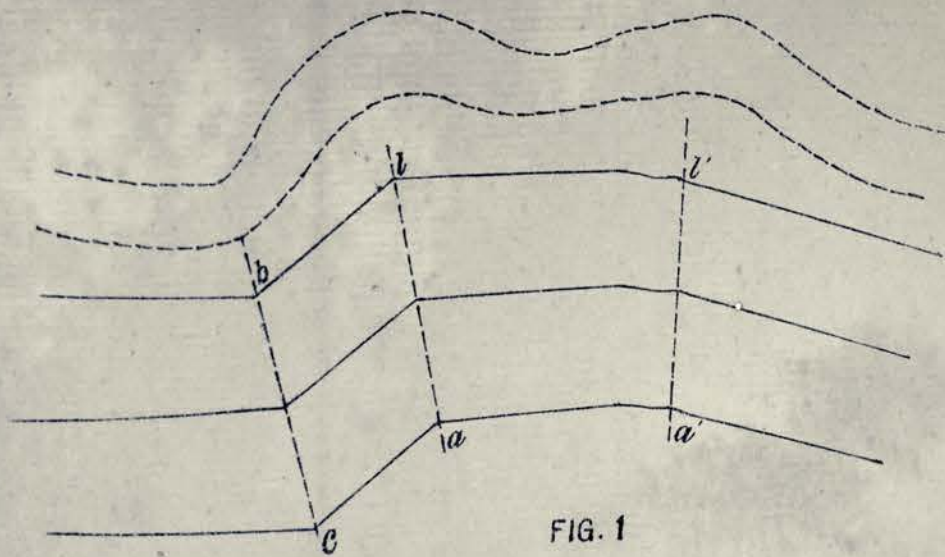


FIG. 1

eb, al, al'. Lines of the points of spina
c closed spina
a a' open spina

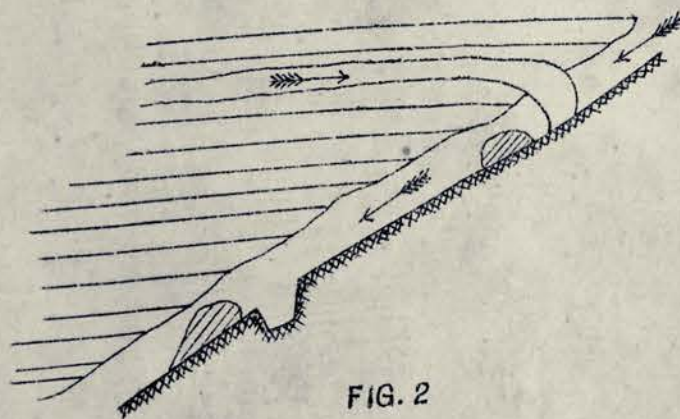


FIG. 2

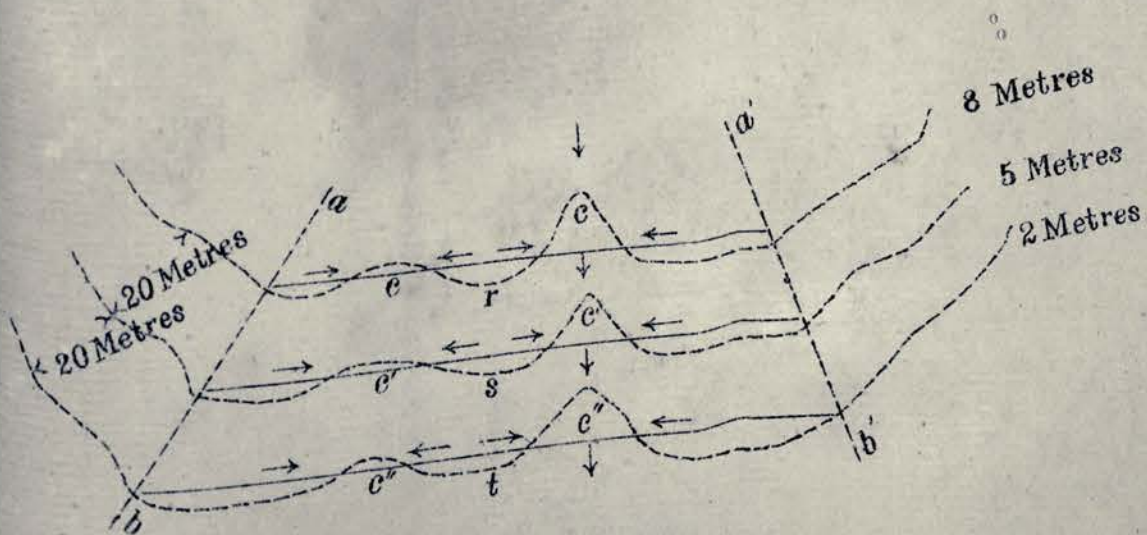
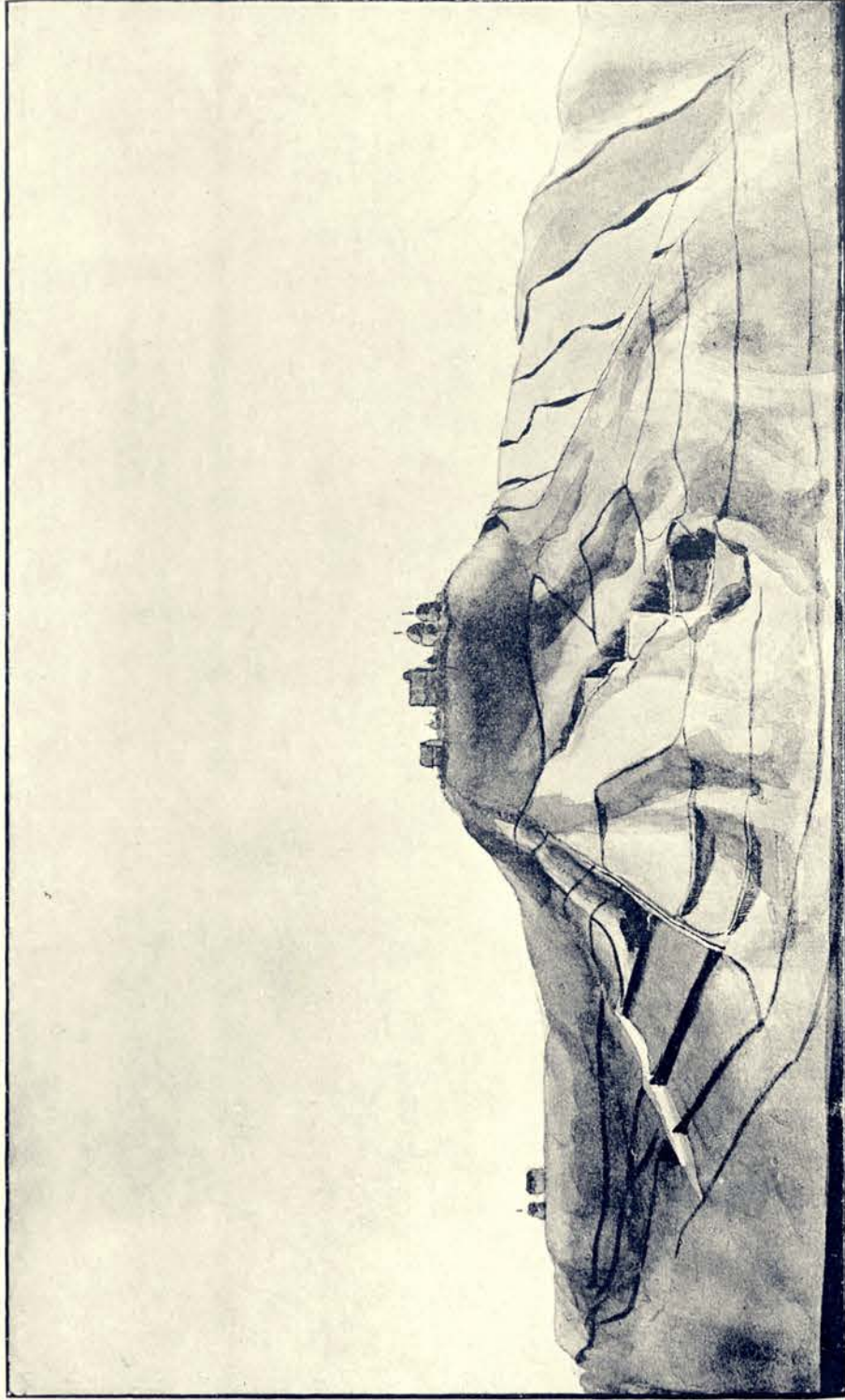


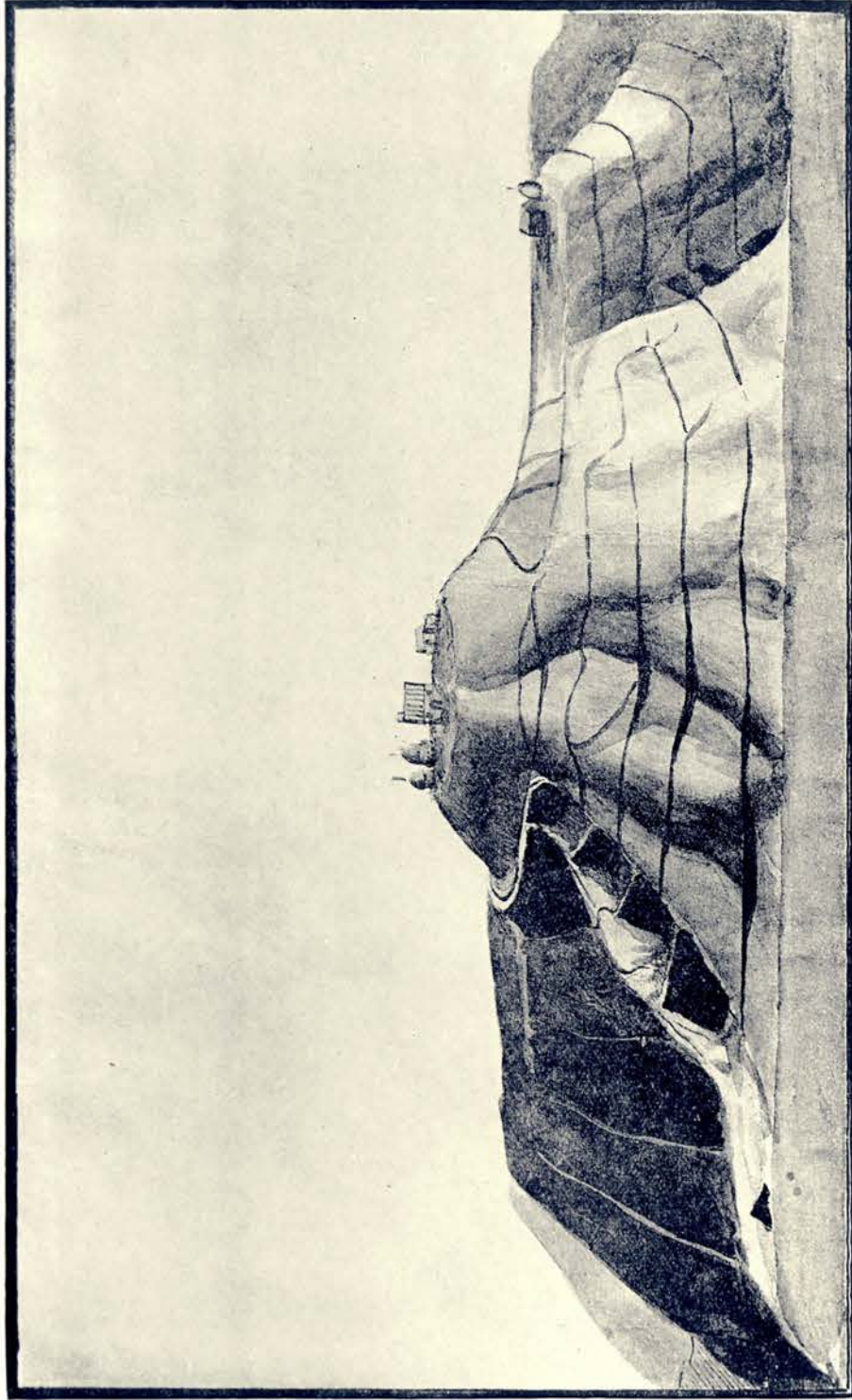
FIG. 3

Plate 15.



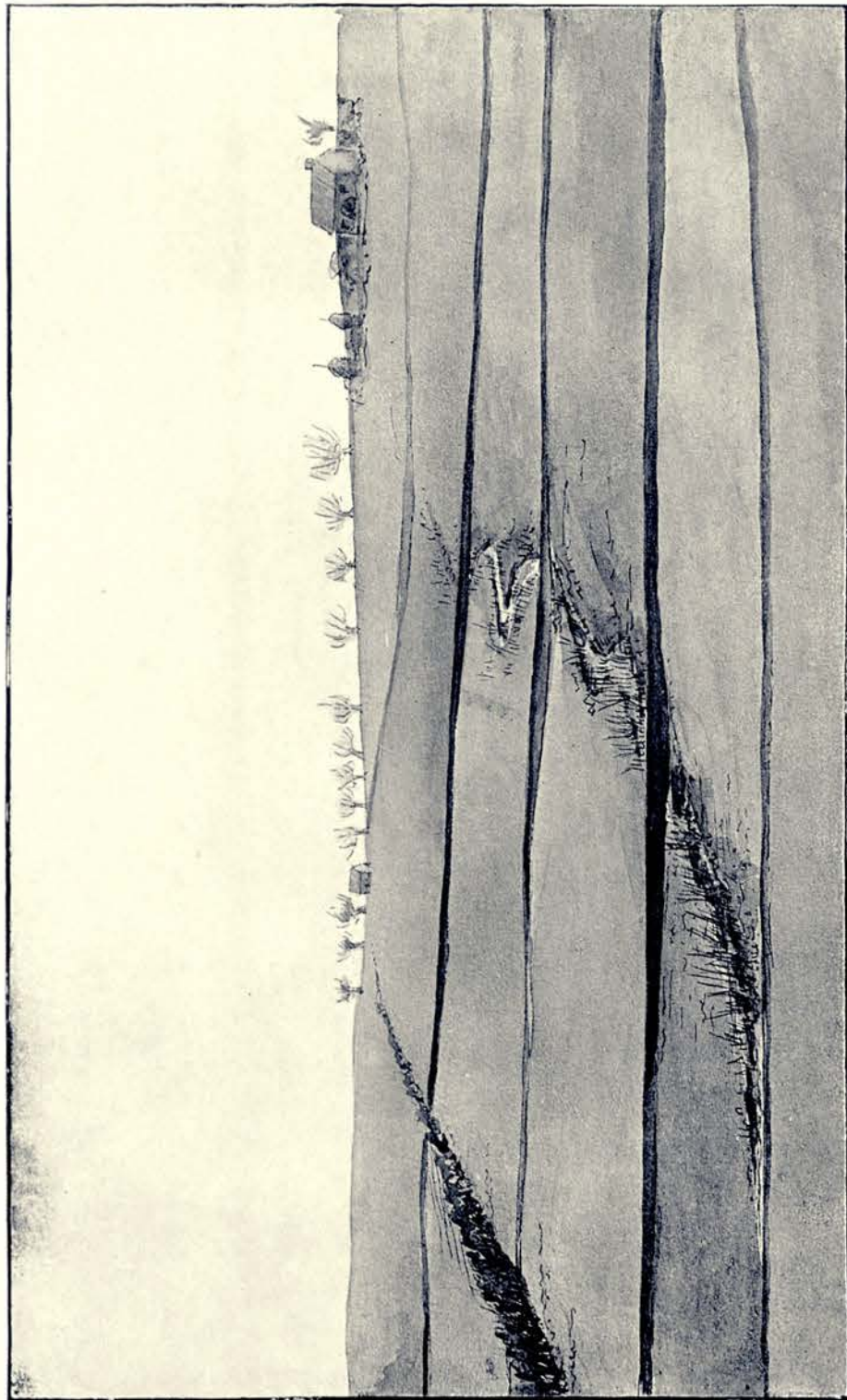
South View of Hill side showing the work of systemization "a spina" and also of Colmata.

Plate 16.



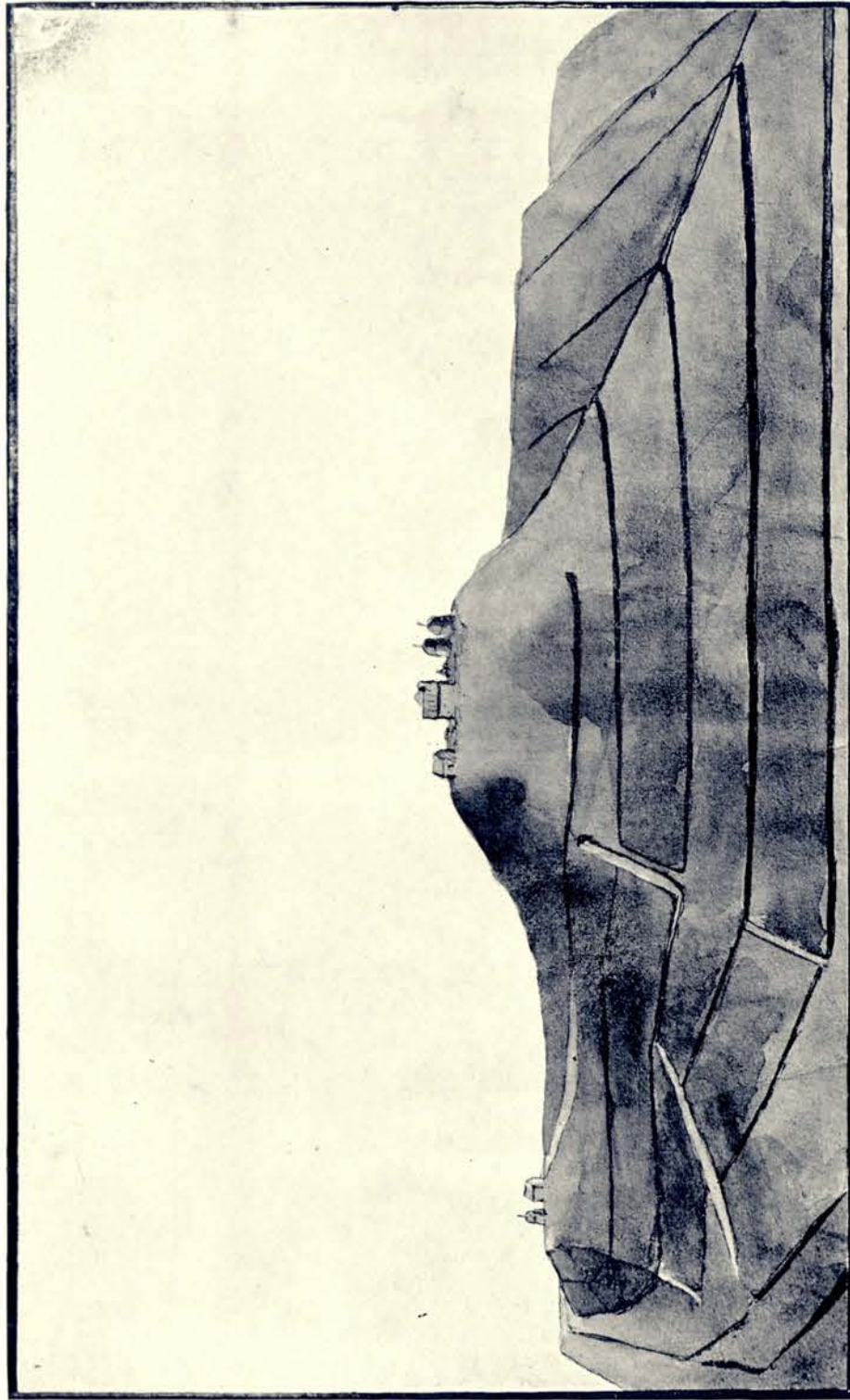
North View of Hill side showing the work of systemization "a spina" and also of Colmata.

Plate 17.

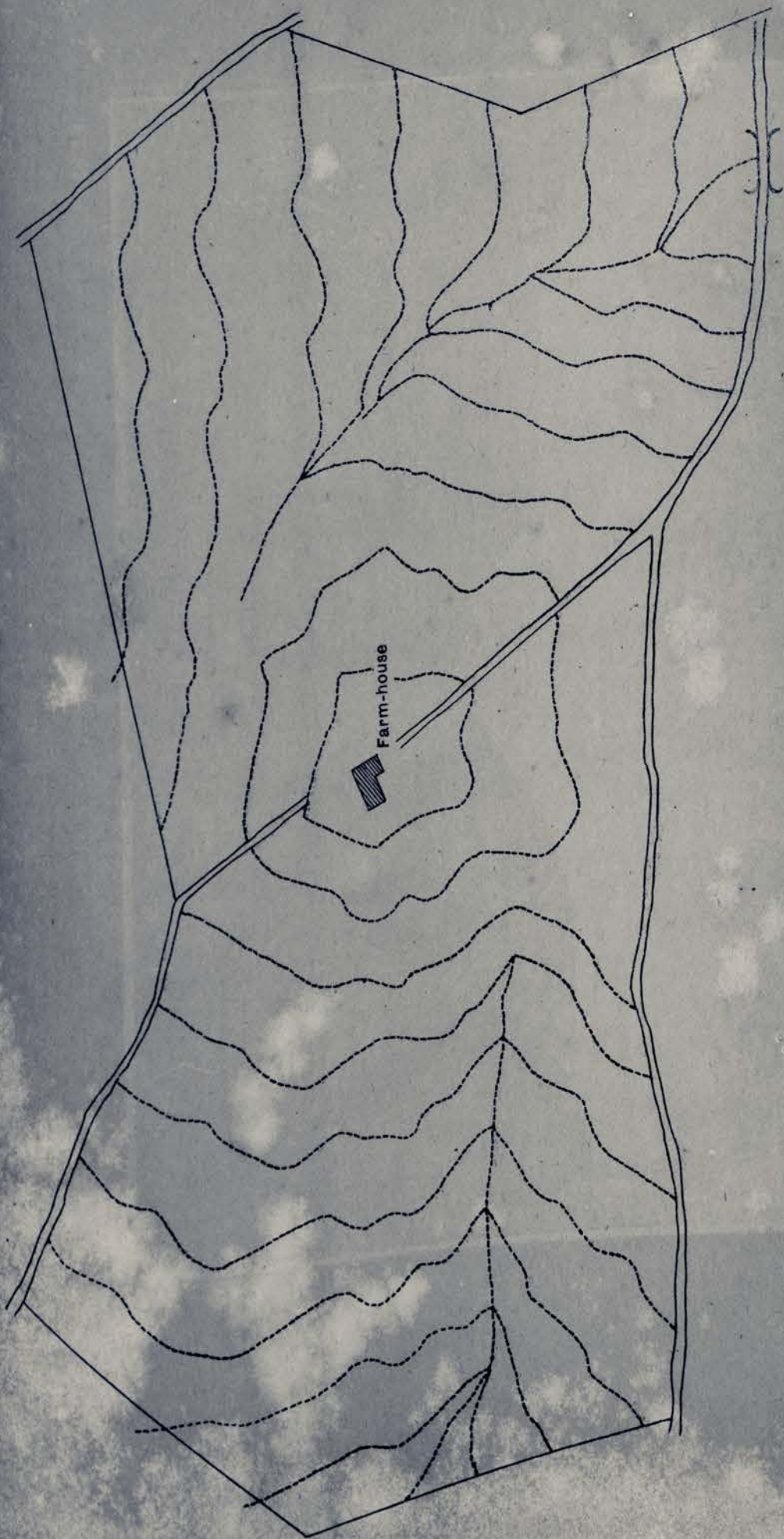


View showing Colmattelle and the ditches for the systemization "a spina."
Taken from a photograph on the farm of the Agricultural School of Macerata.

Plate 18.



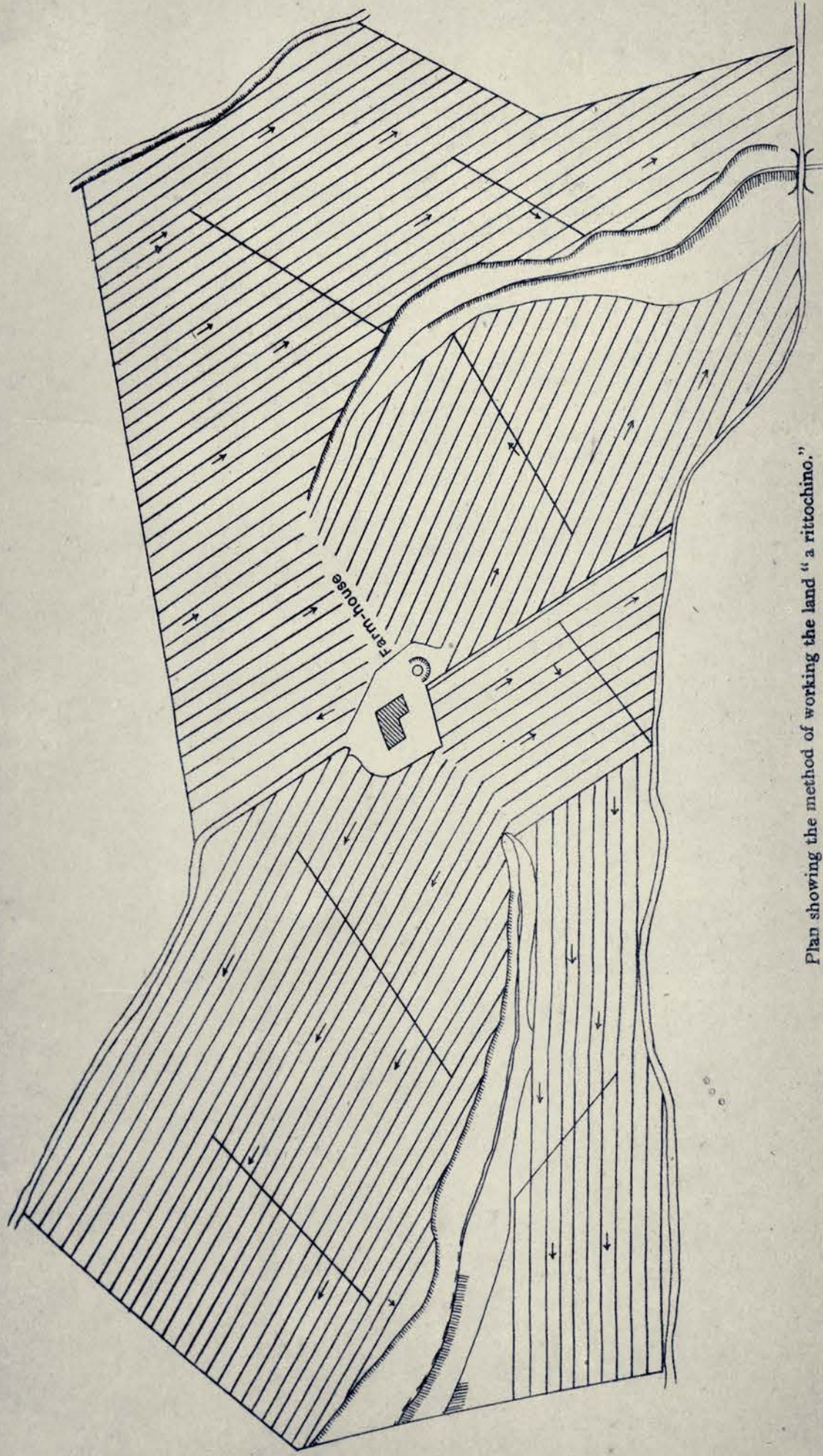
View of the same Hill side shown in Fig. 13 after completion of the work of Colmata.



Contour plan of the Farm to be systematised.

Photo. Michl. and Litho. Dops., Thomason College, Roorkee.

Photo. Zinoo., May, 1902 - No. 3124-170

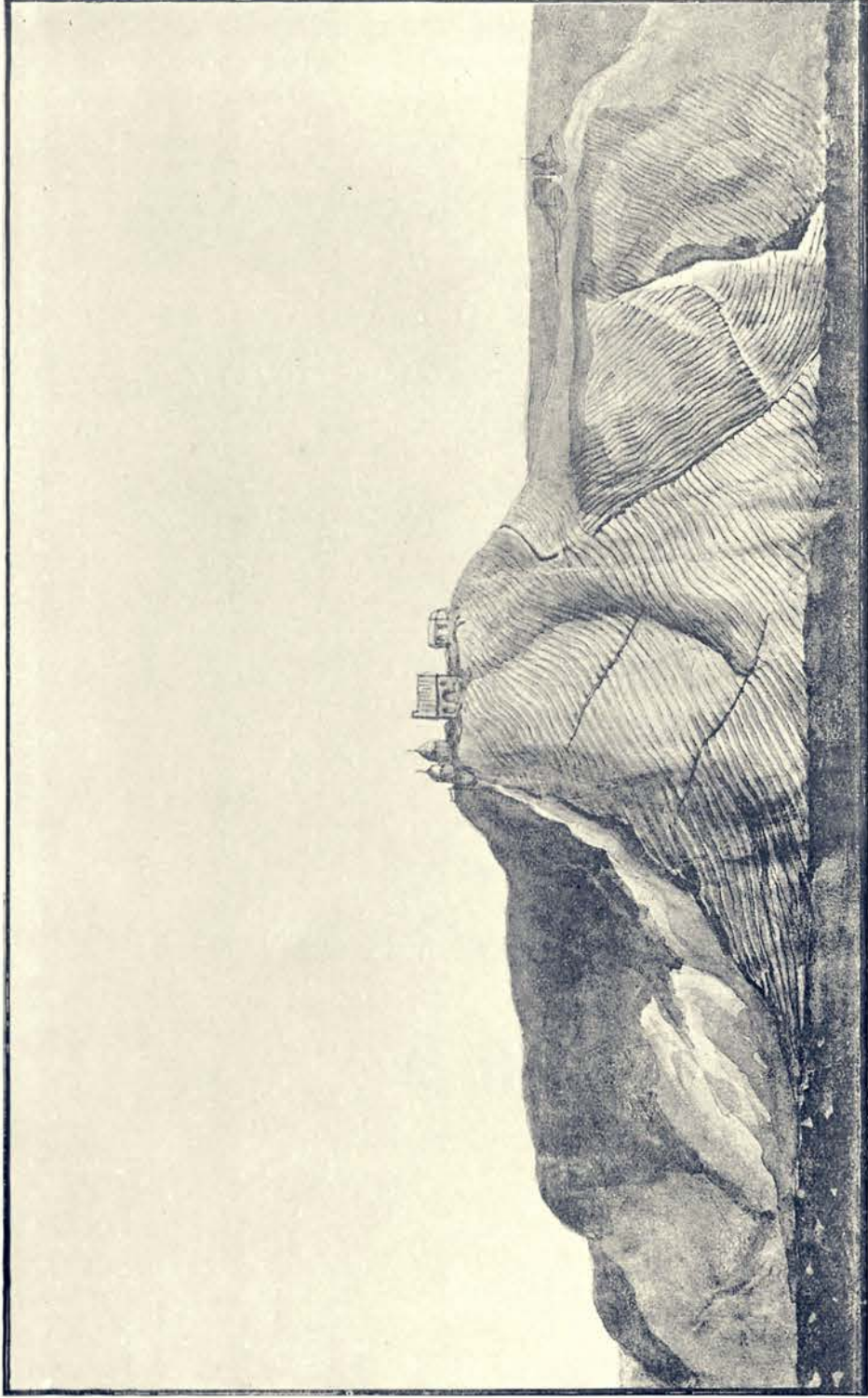


Plan showing the method of working the land "a rittochino."

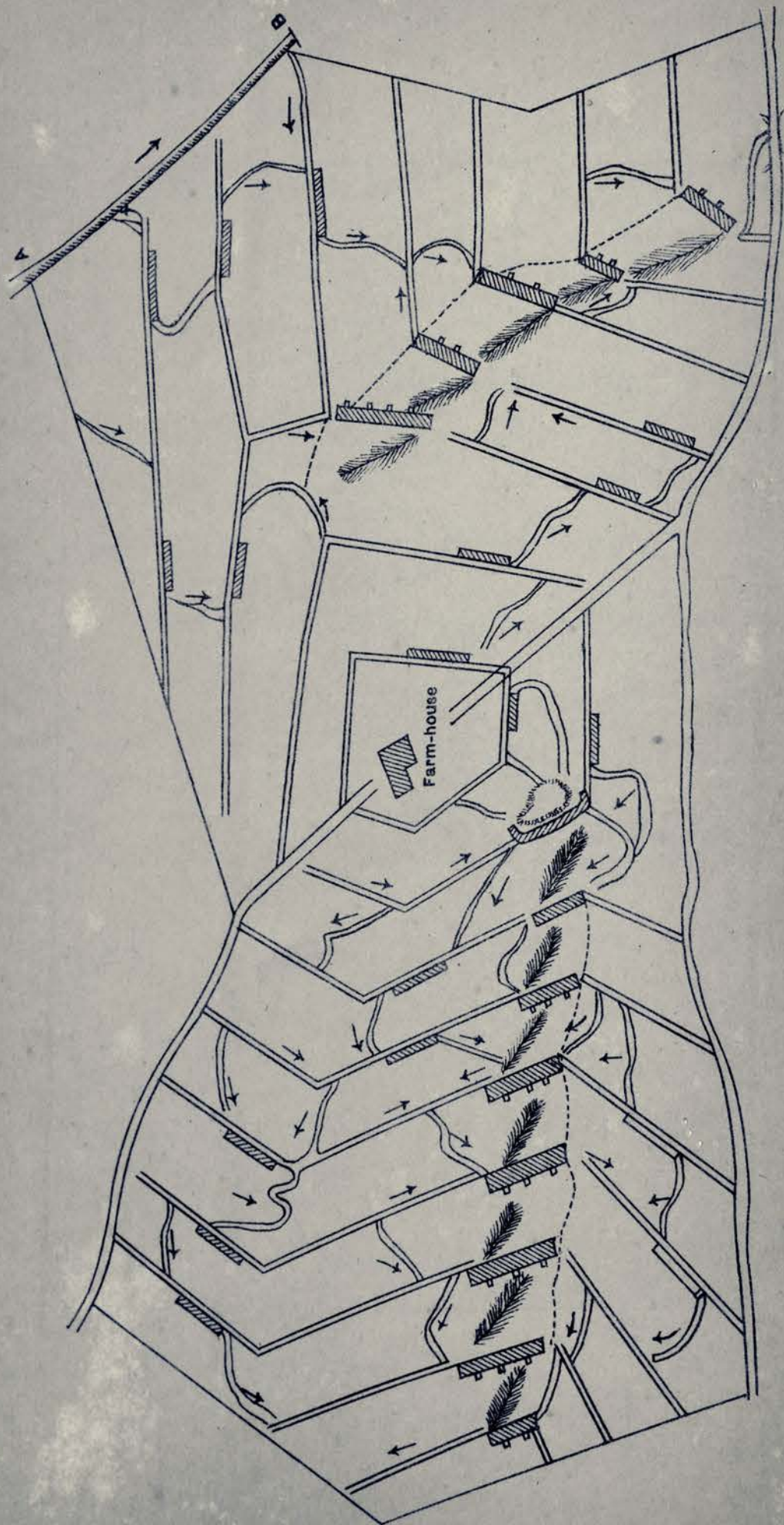
Photo-Zinco. May. 1908— No. 4119-19-170

Photo-Mechi. and Litho. Dept., Thompson College, Roorkee.

Plate 21.

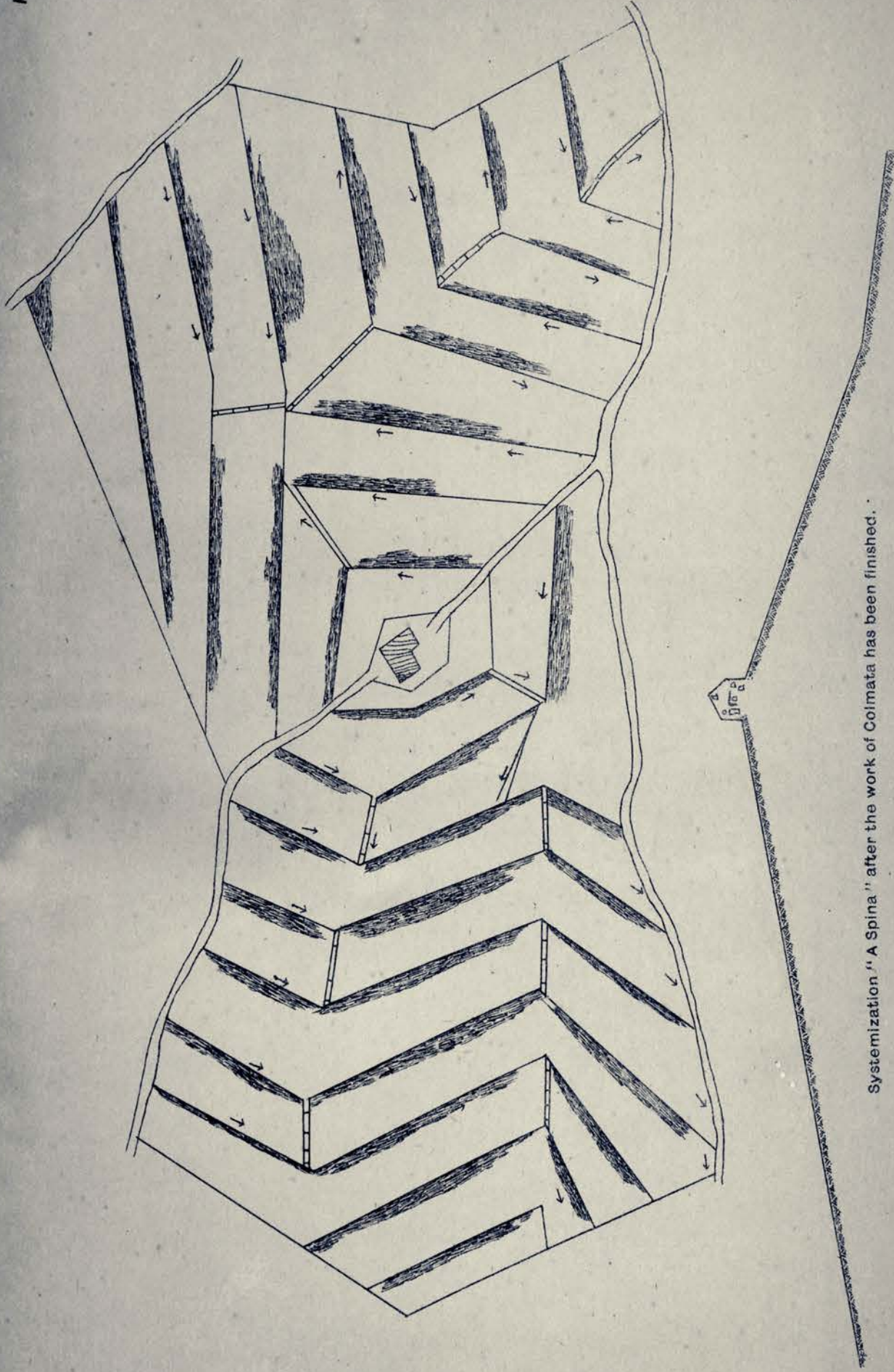


Hill worked on the system of Rittochino.



Plan showing the arrangement of the work of Colmata.

Photo. Ziacon, July, 1908—No. 412-44-170



Systemization "A Spina" after the work of Colmata has been finished.

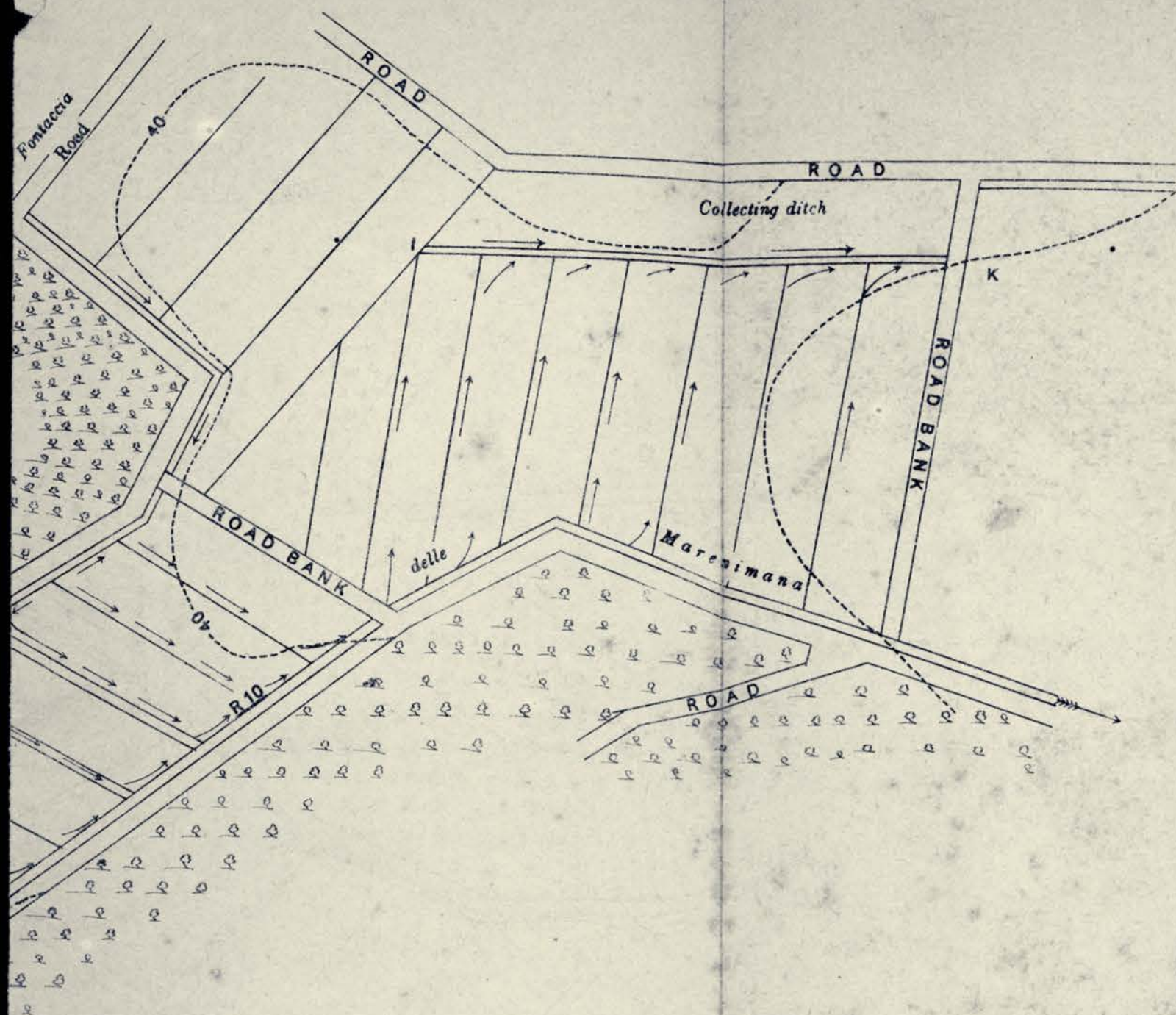


00109242

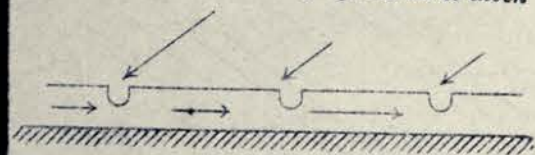
PLAN SHOWING SYSTEM OF COLMATA DI MONTE
ON A PORTION OF MARCHESI RIDOLFI'S ESTATE
AT MILETO.

Scale, 1:2500





Heads of agricultural ditch



Longitudinal Section of silting ditch (no scale).

